THE NICKEL BULLETIN

A SUMMARY OF CURRENT INFORMATION ON NICKEL

SEPTEMBER-OCTOBER, 1951

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VOLUME 24 NUMBER 9-10

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ABSTRACTS OF CURRENT PUBLISHED INFORMATION ON NICKEL AND ITS ALLOYS

GENERAL

Powder Cutting: Review of Processes

R. E. DORE: 'Review of Powder Cutting Processes.' *Welding and Metal Fabrication*, 1951, vol. 19, Mar., June, July, Aug., pp. 91-8; 217-23; 253-58; 268; 301-7.

A comprehensive review, prepared by the author on behalf of Technical Commission No. 1 of the International Institute of Welding.

Part I describes the essential features of the *flux-injection* process (Air Reduction Co., New York); the *iron-rich powder* process (Linde Air Products Co., New York), and the *oxy-kinetic* process (Oxyhydrique International Société Anonyme, Brussels). Equipment required in the respective processes is described, with good illustrations.

Part II deals with health hazards involved in powder cutting; it also contains much information on the mode of operation of the three processes mentioned, and the techniques suitable for cutting the various materials on which they can be used. A considerable amount of the information with regard to specific materials relates to various grades of stainless steel: cutting of bronzes is also included.

Part III comprises a discussion of the metallurgical aspects of the subject, in which connexion the author gives details of oxidation reactions and other relevant data for various high-alloy steels, and describes the effects produced in the heat-affected zones of the materials cut, with particular reference to reactions in nickel-chromium stainless steels. Structures of cut surfaces of steels are illustrated. Problems associated with cutting of cast iron are also reviewed.

Part IV is concerned with the applications of powder cutting. Stainless steel is the main field of use, and it is considered that, just as normal oxygen cutting has become an established method of dealing with carbon and low-alloy steels, powder cutting will eventually be accepted as a standard method of cutting and shaping stainless steels. Uses already developed include many of the cutting operations required in steelworks, where its application has appreciably speeded up operation; removal of risers and surplus material in the foundry, and the cutting out of defects prior to welding. The application of powder cutting is also greatly facilitating many of the cutting and shaping operations involved in fabrication of stainless-steel equipment and machinery: some typical powder-cut sections are described and illustrated. Particular attention is called to the usefulness of the method for 'stack' cutting of thin steel sheet, where the introduction of powder cutting has made possible utilization of all the advantages gained by stack cutting, without any of the problems arising when oxygen cutting is used.

Sub-Zero Properties of Metals and Alloys

See abstract on p. 199.

Electropolishing of Nickel

See abstract on p. 189.

The Pressure-Welding Process: Its Application to Nickel-containing Materials

F. C. KELLEY: 'Pressure Welding: Part I, History; Part II, Cold-Pressure Welding.' *Welding Jnl.*, 1951, vol. 30, Aug., pp. 728-36.

Part I contains a review of the development of pressure welding, including reference to the principal patent and technical literature.

Part II deals specifically with the cold-pressure-welding process developed by the General Electric Company, Ltd. A main feature of this method is the preparation of the surface to be welded, by a combination of pickling and wire brushing. Grit blasting followed by wire brushing has also given good results. The punch assembly, and the hydraulic press in which the welding pressure is applied, are described and illustrated, and the results obtained in welding various similar- and dissimilar-metal joints are tabulated, giving conditions of welding and the properties of the welds. Structures typical of cold-pressure welds are illustrated. The data presented include reference to joints in 18-8/18-8 chromium-nickel steel, nickel/nickel, aluminium/nickel, brass/18-8 steel, brass/nickel, copper/18-8 steel, iron/nickel, iron/18-8 steel, nickel/18-8 steel.

Some of the applications for which this newly developed process has already been commercially employed are described: these relate to welds of aluminium/aluminium, copper/copper and aluminium/copper, as used, for example, in refrigerator containers and tubing.

'Sigma' Welding Process

See abstract on p. 216, entitled 'Sigma Welding of Nickel-Chromium Stainless Steels.'

NICKEL

Conservation of Nickel: U.S. Orders

'National Production Authority Order M.80.' *Reprint issued by Jnl. of Commerce*, Aug., 1951.

This Order provides for complete allocation control, in U.S.A., of alloying elements. It supersedes Orders previously issued relating to individual materials, e.g., nickel, molybdenum.

By the terms of the new Order, all melters and processors are required to file proposed melting and processing schedules, and data concerning inventories, and the users are placed under obligation to obtain N.P.A. authorization for production or processing.

Following a general discussion of the scope of the

Order, and definition of the terms used, schedules are given covering nickel (including nickel plating), nickel-containing stainless steels, cobalt, tungsten, alloying materials as used in iron and steel (molybdenum, niobium and tantalum), high-nickel alloys, nickel silver, tool steels and high-speed steels. The nature of the materials subject to allocation, prohibited uses, and requirements to be satisfied in applying for allocations, are indicated.

Production, Consumption and Future Prospects of Nickel and Cobalt

C. A. SCARLOTT: 'The Present and Future of Nickel and Cobalt.' *Materials and Methods*, 1951, vol. 34, July, pp. 61-5.

The article gives a condensed but comprehensive account of the world sources of nickel (indicating the types of ore found in the respective localities), and a bird's-eye view of the history of development and consumption. The unusual versatility of nickel as an alloying metal is illustrated by reference to its use in alloy steels, cast iron and non-ferrous materials, in magnetic alloys, and in the chemical industries. Particular attention is directed to the many uses of Monel. Figures for the average consumption of nickel in the U.S.A. during 1946-1949, in various industries, are tabulated.

It is pointed out that although at present the metal is 'strategic', there is no permanent shortage of nickel. Extensive deposits exist in many parts of the world, the full development of which is being actively promoted by investigation of methods of extraction specially suited to particular grades of ore, and by the improvement of transport facilities, etc. The true extent of the Sudbury deposits is still unknown, but at the end of 1950 the figure given for proved ore reserves in this area was 212 million tons (6·8 million tons of nickel-copper content).

A similar review is made of the sources, production methods, consumption and future prospects of cobalt. In this case also long-range supply is considered to be adequately safeguarded by known reserves.

Structure of Single Crystals of Nickel

S. YAMAGUCHI: 'On the Etched Surfaces of Nickel Single Crystals.' *Jnl. Applied Physics*, 1951, vol. 22, July, pp. 983-4.

WALKER *et al.* reported in 1949 that in a nickel single crystal there are eight etch planes (111): their observations were made by means of optical and X-ray examination. The present author, using electron-microscopy and diffraction methods, confirmed the earlier findings. Details of experimental procedure are given, together with electron micrographs of three single-crystal specimens.

Thermal Conductivity of Nickel-containing Materials

See abstract on p. 200.

Oxidation of Nickel and of Cobalt

See abstract on p. 210.

Magnetic Susceptibility of Nickel under Tension

H. J. PEPPIATT and B. N. BROCKHOUSE: 'The Initial Susceptibility of Nickel under Tension.' *Jnl. Applied Physics*, 1951, vol. 22, July, pp. 985-6.

The authors critically consider expressions proposed by BECKER, and by DÖRING, and experimental results obtained by SCHARFF, for initial susceptibility of nickel under tension. They also report their own tests, made on nickel of 99·99 per cent. purity. A fuller account of the work is to be published in the Canadian Journal of Physics.

Magnetostriction of Nickel and Nickel Alloys at Low Temperatures

J. SMIT: 'Magnetostriction of Ferromagnetic Metals and Alloys at Low Temperatures.' *Physica*, 1951, vol. 17, June, pp. 612-27.

Magnetostriction of pure nickel and iron and of some nickel-iron, nickel-cobalt and nickel-copper alloys, and Heusler's alloy, has been measured at room temperature and the temperatures of liquid nitrogen and liquid hydrogen (−196° and −252·8°C., respectively).

Behaviour of the metals is essentially different from that of the alloys: a maximum in magnetostriction is observed for alloys having about one Bohr magneton per atom. Positive difference found between longitudinal and transverse resistance is explained by means of spin-orbit interaction.

At low temperatures the pure metals show increase in resistance with increasing fields, just as do non-ferromagnetic metals. From this the value of the internal field, acting on the conduction electrons, could be determined: it was found to be approximately equal to the induction, B.

Electrical Properties of Nickel Oxide

C. A. HOGARTH: 'Some Conduction Properties of the Oxides of Cadmium and Nickel.' *Proc. Physical Soc.*, Sect. B, 1951, vol. 64, Aug. 1, pp. 691-700.

The paper reports measurements of the electrical conductivity and thermoelectric power of specimens of black and of green nickel oxide, and of cadmium oxide, as functions of temperature and of oxygen pressure. The results were found to be in general agreement with theories previously proposed by WAGNER and by the present author. The data obtained are used to verify Wagner's concept of a differential thermoelectric circuit, and a band model for CdO is proposed.

Nickel and Nickel-Alloy Pipe and Tubing

See abstract on p. 194.

Electropolishing of Nickel

P. A. JACQUET: 'Electrolytic Polishing of Nickel.' *Metal Progress*, 1951, vol. 60, Aug., p. 65.

Commenting on recommendation made by WENSCH, of an orthophosphoric acid solution for electropolishing of nickel (*ibid.*, 1950, vol. 58, Nov., p. 735; *Nickel Bulletin*, 1951, vol. 24, No. 1, p. 7), Jacquet remarks

that the illustration shown by Wensch is somewhat dappled, indicating some variation in the surface level of the specimen polished. The writer's experience has been that better results are obtained in polishing nickel by the use of a solution containing perchloric acid one part, acetic anhydride four parts, used with current of 18 amp./sq. dm. Such a solution will polish nickel, even metal containing insoluble inclusions, to a surface which is perfectly smooth when viewed at a magnification of 500 diameters.

Determination of Traces of Nickel in High-Purity Iron Alloys

B. E. HOPKINS, G. C. H. JENKINS and H. E. N. STONE: 'Production of High-Purity Iron and Iron Alloys on a 25 lb. Scale.' *Jnl. Iron and Steel Inst.*, 1951, vol. 168, Aug., pp. 377-83. (British Iron and Steel Research Association Paper MG/A/220/50.)

The paper describes methods and equipment developed in the National Physical Laboratory for production of iron and iron alloys of high purity. An appendix gives an account of investigations on methods of analysis for determination of impurities within the range 0·001-0·01 per cent. in high-purity iron. Procedure for estimation of carbon, silicon, sulphur, phosphorus, manganese, nickel, copper, chromium, and aluminium are described.

For estimation of nickel, iron is removed by an ether separation, and this is followed by dimethylglyoxime precipitation of nickel. The latter is determined colorimetrically, by the iodine-dimethylglyoxime reaction: see below:—

'*Method*

Dissolve a 10-g sample in acid, and carry out an ether separation of iron. Precipitate nickel with dimethylglyoxime in alkaline tartrate solution. Filter, dissolve the precipitate in hydrochloric acid, and evaporate the solution with a small amount of sulphuric acid, destroying organic matter by oxidation with nitric acid. Determine the nickel colorimetrically by the following procedure: To the weakly acid solution, add 10 ml. of 50 per cent. ammonium citrate, 5 ml. of 0·1*N* iodine, 20 ml. of 1:1 ammoninium hydroxide, and 5 ml. of dimethylglyoxime (5 per cent. in alcohol). Allow to stand for 15 min., and measure the orange-red colour by an absorptiometer or spectrophotometer.

Beta-Isothioureidopropionic Acid as a Reagent for Determination of Nickel

L. J. UHLIG and H. FREISER: 'Reaction of Nickel (II) and Beta-Isothioureidopropionic Acid.'
Analytical Chemistry, 1951, vol. 23, July, pp. 1014-16.

The investigation reported was initiated to ascertain the reactions of beta-isothioureidopropionic acid, a compound which has recently been synthesized, with various cations, and to evaluate its possible usefulness as an analytical reagent.

Preliminary tests showed that in ammoniacal solution a reaction of this acid with nickel (II) ions resulted in formation of a highly coloured complex; this observation led to the development of a colorimetric procedure for determination of trace amounts of nickel (in concentrations of 0·1 to 1·0 mg. in 50 ml., with an average error of about 0·005 mg.). Details of procedure are given.

By this method nickel can be estimated simply, rapidly and accurately, in presence of aluminium, zinc, and a moderate amount of copper. Iron and cobalt interfere.

The nature of the reaction is not yet fully understood, but it is postulated that beta-mercaptopropionic acid, formed by hydrolysis, chelates with the nickel, to give the coloured substance.

Evaporated Nickel Films as Catalysts

C. KEMBALL: 'The Reaction of Methane and Deuterium on Evaporated Nickel Catalysts.'
Proc. Royal Soc., Ser. A, 1951, vol. 207, July 23, pp. 539-54.

The object of the investigation was to follow, by means of a mass spectrometer, the production of each deuteromethane in the reaction of methane and deuterium, particularly in the initial stages, in order to find whether the compounds containing higher amounts of deuterium were formed by successive reaction or independently. The work of BEECK, SMITH and WHEELER, in 1940, had indicated the importance of evaporated metal films, as providing catalysts of known structure and purity. This determined the method of preparation of the nickel catalyst, which is described in detail.

Resistance Welding of Nickel and Nickel-base Alloys

See abstract on p. 194.

The Pressure-Welding Process: Its Application to Nickel-containing Materials

See abstract on p. 188.

ELECTRODEPOSITION AND OTHER COATING METHODS

Conservation of Nickel in Plating

'Conservation of Nickel in Plating.' *Metal Industry*, 1951, vol. 79, Aug. 17, pp. 128-30.

The Research Committee of the British Non-Ferrous Metals Research Association which is investigating the quality of nickel electrodeposits has recently been considering the steps which can be taken throughout industry to conserve nickel in electrodeposition, by ensuring its efficient use and by avoiding wastage. The present communication embodies the views and recommendations of the Committee: its scope is indicated below.

Thickness of Plate

The Committee considers that to apply thinner nickel coatings than hitherto would at present be a retrograde step, and strongly recommends the maintenance of established standards in this respect. Attention is drawn to the use of copper undercoats in partial substitution for nickel, as permitted by the current

B.S.1224. The Committee endorses the use of copper according to this specification wherever possible.

Overplating

Much nickel may be wasted in plating other than 'significant' surfaces, and by overplating some parts of significant surfaces in order to obtain specified minimum thicknesses on other parts. To obviate this unnecessary expenditure of metal, more careful attention should be given to design of articles to be plated and to jigging arrangements.

Avoidance of Waste

Much entirely avoidable waste is believed to be occurring in many plating shops. Means for improvement are considered from three aspects:—

(1) *Waste as Metal*

Nickel as metallic scrap is more readily used for alloying than nickel wasted in any other form, but the amount of such scrap should be rigidly minimized. The Committee advocates the use of coated jigs and of anode-stub economizers, also the use of electrolytic methods of removal of metallic impurities (other than iron). Conditions should be carefully controlled, to avoid use of too-high current densities, in purification.

(2) *Waste as Sludge*

The amount of nickel so wasted is not considered to be important, but it is emphasized that solution which may be rejected with the sludge, for fear of contaminating the bath, is valuable, and the nickel from it should be reclaimed.

(3) *Waste as Solution*

The greatest contribution which can be made by the plating trade to economizing in nickel is by avoiding waste as plating solution. Leaking pumps, filters, etc., must be avoided, and, above all, dragout losses must be avoided. The Committee strongly recommends the use of dragout tanks for all work except the plating of zinc and aluminium. The memorandum makes detailed recommendations with regard to methods of calculating dragout loss, and means which may be adopted for prevention of such waste, e.g., chiefly by use of dragout-recovery rinse tanks, the operation of which is discussed. Further means of minimizing dragout loss are the working of the solution at the lowest salt-concentration compatible with satisfactory plating performance, and the use of ion-exchange filters to scavenge nickel from the final rinse waters.

F. TAYLOR: 'Material Economy: Conservation of Nickel in Electroplating.' *Electroplating*, 1951, vol. 4, Aug., pp. 249-51; Sept., pp. 285, 291.

This article contains a practical discussion of means which may be adopted by the jobbing plater to ensure economical use of nickel and optimum results from the amount of anodes and salts available.

Recommendations are made with regard to maintenance of the purity of the solution, correct wiring and jigging of work, use of auxiliary anodes, control of operating conditions, use of scrap anode material, avoidance of drag-out, etc. The importance of improving the general standard of knowledge of the staff employed in the plating shop is also emphasized.

Cleaning of Metals Prior to Electroplating: A.E.S. Research Report

H. B. LINFORD and E. B. SAUBESTRE: 'Cleaning and Preparation of Metals for Electroplating. III. Degreasing Evaluation Tests: The Atomizer Test.' *Plating*, 1951, vol. 38, July and Aug., pp. 713-17; 847-55.

This progress report is concerned with development of a new degreasing-evaluation test required to be sensitive, reproducible, inexpensive, and easy to apply.

As pointed out in the Critical Survey of the Literature (*ibid.*, 1950, vol. 37, pp. 1265-9; 1951, vol. 38, pp. 60-5, 158-66; *Nickel Bulletin*, 1951, vol. 24, Apr., p. 69), failure of plating may arise from a number of causes. In the survey causes of failure were classified, and in a later paper it was indicated that the work of the project would begin by a study of the effects of oil residues on plating. The present report is, therefore, concerned only with tests designed to reveal the presence of oil.

Consideration of all the factors involved suggested the advisability of developing a method based upon some form of wettability test: the atomizer test described in the present report is essentially of this nature. It involves the following steps:

(1) Evaporation of all moisture from the plated surface.

(2) Spraying of water against a panel of the plated material, using an atomizer.

(3) Measurement of areas covered by a thin, uniform film of water.

Details are given of equipment and procedure, and a report is made of results obtained on nickel-plated panels which had been oiled, and afterwards cleaned to various degrees in alkaline solutions.

The atomizer test proved capable of distinguishing between the various degrees of cleaning, the differences being more clearly apparent with the lard-oiled than with the mineral-oiled specimens.

The authors discuss the theory underlying wettability tests and the differences between the atomizer test and other wettability methods.

Appendices contain a statistical analysis of atomizer-test results, and discussion of the reproducibility of the test, effects of irregularities in test procedure, and drop-size distribution in this and other atomizer forms of test. A comprehensive *bibliography* is attached to the report.

Conservation of Nickel: U.S. Orders

See abstract on p. 188.

Levelling in Electrodeposition

A. BREGMAN: 'Leveling Solutions.' *Metal Progress*, 1951, vol. 60, July, pp. 56-60.

During the past few years a growing interest has been shown in the development of electroplating solutions which give a coating smoother than the basis metal on which it is deposited. Such action is designated 'levelling' or 'smoothing': the primary advantage of such an effect is saving of labour in polishing and buffing of the deposited metal.

This article gives a good summary of the literature, from the paper by GARDAM: 'Smoothing Action as a Mechanism in Bright Nickel Plating' (*Jnl.Electrodepositors' Tech. Soc.*, 1946-47, vol. 22, pp. 155-68; *Nickel Bulletin*, 1948, vol. 21, No. 1, p. 7). The major part of the review is based on papers presented at the 1950 Convention of the American Electroplaters' Society (for abstracts see *Nickel Bulletin*, 1951, vol. 24, No. 4, pp. 69-72).

Sea-Water-Spray Testing of Metallic Materials

See abstract on p. 213.

Detection of Porosity in Electrodeposited Nickel Coatings

A. KUTZELNIGG: 'New Test Papers for Detection of Porosity and for Identification of Metals.' *Metalloberfläche*, 1951, vol. 3, Aug., pp. B113-15.

Introductory discussion of the author's earlier observations on a simplified form of the nickel dimethylglyoxime test for nickel, and of related identification tests (see *Nickel Bulletin*, 1951, vol. 24, No. 2, p. 30) is followed by a short note on the standard ferroxyl test. The scope of the information obtainable by that test is considered, and it is pointed out that the need exists for a test which reveals only the areas at which the pores extend through to the basis material. The author claims that this requirement is satisfied by use of a paper impregnated with α-nitroso-β-naphthol, a reagent which gives, with iron salts, a difficultly soluble blue-green complex. Methanol is used as the solvent medium for the reagent. To make the test, the impregnated paper is moistened with water, and after contact with the coating for 5 minutes porous areas in nickel or tin coatings are revealed by the appearance of blue-green spots. The nickel plating is not attacked, since α-nitroso-β-naphthol forms no compound with nickel.

Comparative tests made with a solution of 50 g./L. of potassium ferricyanide confirmed the findings of THON that neither electronickel foil nor sheet iron was attacked, whereas solutions containing, respectively, 50 g./L. potassium ferricyanide+0·2 g./L. sodium chloride, and 10 g./L. potassium ferricyanide+5 g./L. sodium chloride produced coloured corrosion products on both nickel and iron, after only short times of contact. The corrosive effect of the 50/0·2 solution was particularly severe: comparative effects of this solution and of the α-nitroso-β-naphthol mixture on nickel foil are illustrated, and the comparative effects of ferroxyl reagents and Porotest α-nitroso-β-naphthol reagents are also demonstrated, with regard to their behaviour on iron and on tinned sheet.

It is believed that other organic reagents as well as α-nitroso-β-naphthol may also be suitable for use in the series of Porotest papers, but the experiments with alternatives are not yet sufficiently advanced to permit a definite conclusion to be reached.

Brief reference is also made to the porosity testing of coatings on non-ferrous bases, e.g., silver on nickel (using dimethylglyoxime-impregnated papers), and silver on brass and copper (using a test paper impregnated with haematoxylin). This test (Porotest paper II) is based on the blue colouration produced by reaction between copper-base materials and haematoxylin, a reagent which forms no coloured complex with silver. An illustration also shows the use of this type of paper for testing porosity of nickel coatings on iron.

Silver Plating of Inconel

L. J. COOK: 'Silver Plating on Inconel.' *Rev. Scientific Instruments*, 1951, vol. 22, July, p. 542.

In production of components for high-frequency electrical equipment there are many applications of silver plating in which it is essential that the surface should have the highest possible electrical conductivity. This requirement is easily satisfied by plating a thickness of more than 0·001 in. on most of the common metallic materials, but in some cases attempts to obtain high conductivity in thinner films plated on Inconel and stainless steel have been unsuccessful, in spite of the use of special technique.

The work described in this note was done in connexion with preparation of Inconel tubing to be used as a centre conductor of a coaxial cable: in order that the cable should have the required frequency characteristics it was essential that the silver plating should show an electrical conductivity of 90 per cent.* The procedure described below has been found to produce, consistently, conductivities of the order of 95 per cent. of the value for pure bulk silver,* in films 0·0002 in. thick.

'*Preliminary cleaning*. In laboratory tests satisfactory results were obtained by cleaning with soap and water, or with organic solvents. In production it was found more convenient to clean cathodically, in a proprietary alkaline cleaning solution, used at 20 amp./sq. ft. for one minute, followed by a water rinse.

'*Electrolytic Pickling*. The purpose of this step was to remove the passive chromium-oxide and nickel-oxide films, and to produce a surface structure fine in comparison with the thickness of the silver film to be plated. This is considered to be the most critical step in the plating cycle: it was controlled by microscopical observation of the pickled surface. Treatment comprised anodic pickling in 10 per cent. hydrochloric acid (a typical treatment is given as 35 amp./sq. ft. for three minutes), after which the loosely adhering oxide can be removed by rubbing with a cotton cloth, followed by thorough water rinsing. Optimum current density varied over a wide range, depending on the condition of the alloy.

'*Nickel Strike*. Adherence was promoted by plating at 75 amp./sq. ft. for 10 minutes, in a high-chloride nickel-strike bath, and subsequent rinsing.

'*Silver Strike*. The work was struck at 20 amp./sq. ft. for 30 seconds, in a bath containing (per gal.) AgCn 0·9 oz., KCN 10 oz., K_2CO_3 2 oz.

'*Silver Plating*. The plating bath contained (per gal.): AgCN 4·8 oz., KCN 8·0 oz., K_2CO_3 6·0 oz. No brightener was used.'

**The electrical resistivity of pure silver, melted and annealed in vacuum, is taken as $1{\cdot}59\times10^{-6}$ ohm-cm. at 20°C. All relative conductivities given in this note are based on that value.*

Plating of Stainless Steels

J. HAAS: 'Plating of Stainless Steel.' *Machinist*, 1951, vol. 95, Aug. 18, pp. 1250, 1252.

The information given is substantially identical with that appearing in *Metal Finishing*, 1951, vol. 49, June, pp. 50-4: see detailed abstract in *Nickel Bulletin*, 1951, vol. 24, No. 6, June, p. 172.

Influence of Electrodeposited Nickel Coatings on the Mechanical Properties and Fatigue-Resistance of Steel

J. O. ALMEN: 'Fatigue: Loss and Gain by Electroplating.' *Product Engineering*, 1951, vol. 22, June, pp. 109-16.

A critical survey of the literature, which introduces this paper, leads to the conclusion that electrodeposited metal coatings are harmful to the fatigue strength of the basis steel broadly in proportion to the magnitude of the residual tensile stresses present in the coatings. It is admitted that such proportionality is an over-simplification, since other factors such as adhesion, relative yield strength of basis metal and of coating, ductility, and the manner in which the tests are conducted, alter the magnitude of the deleterious or beneficial effects in individual cases.

In order to obtain additional information on the effects of residual stresses in electrodeposited hard metals, the Research Laboratories Division of General Motors Corporation initiated a search for methods of plating which would develop residual compressive stresses in electrodeposited nickel coatings. It was anticipated that three advantages might be so gained: (1) loss of fatigue strength frequently associated with the presence of plated coatings might be avoided, and increase in fatigue strength possibly attained; (2) the beneficial effect of compressively stressed metal coatings would provide further proof of the influence, on fatigue-resistance, of residual stresses, and (3) resistance to rusting of plated steel surfaces could be improved by depositing the metals in a state of compression.

Methods developed for measurement of residual stresses present in coatings (and used by Almen) are described in a paper by PHILLIPS and CLIFTON (*Proc. Amer. Electroplaters' 34th Ann. Convention*, 1947, pp. 97-110: *Nickel Bulletin*, 1947, vol. 20, No. 10, p. 145). Experimental data are shown, in the present paper, on residual stress present in electrodeposits of nickel made from (1) a Watts bath, on steel, and (2) proprietary baths of various types, on steel and on bronze. These show a very wide range: significant stress variations were observed as a function of bath temperature.

The immediate goal of the experiments, deposition of coatings having compressive residual stresses, was attained by use of the bath and operating conditions shown below.

Cleaning Procedure

Degreasing: cathodic cleaning for three minutes; hand-scrubbing with pumice; cathodic cleaning for 30 seconds; water rinsing; anodic treatment in concentrated sulphuric acid at 6 v. for 1 minute; water rinsing.

Plating Conditions

Solution A. Bright-nickel bath containing:—

	oz./gal.
Single nickel salts, $NiSO_4.6H_2O$ ..	40
Nickel chloride, $NiCl_2.6H_2O$ ..	8
Boric acid, H_3BO_3	5
Non-pitting agent	0·08
Brightener A	0·125% by vol.
Brightener B	0·08

pH 3·5-4·8; temperature 115°-140°F. (46°-60°C.); 40 amp./sq. ft. for the time required to deposit the desired thickness: 1200 amp. min./sq. ft.=0·001 in. nickel. The specimen should be rotated, in order to obtain uniform thickness of coating.

Solution B

This solution, which also produced coatings showing residual compressive stresses, was a newer type of bright-nickel bath, which is easier to control than Solution A. No details of composition are given.

Having satisfactorily established conditions for controlled-stress coatings, the General Motors laboratory prepared specimens (1) residually stressed in tension (25,000 p.s.i.) and (2) residually stressed in compression (6,000 p.s.i.). These were tested, in a United States Government laboratory, in comparison with unplated polished specimens of the steel used for the plated samples. The results (shown in a graph) confirm the superiority, in fatigue strength, of the 'compressive-stress'-coated specimens, in comparison with the 'tensile-stressed' specimens, but do not indicate any marked improvement in the 'compressive-stress'-plated specimens over the unplated steel. In this connexion, it is pointed out that the unplated samples were in a highly polished condition, and that such polishing induces residual compressive stresses sufficiently great to increase the fatigue limits of rotating-beam steel specimens by 10-15 per cent.

It would not be expected that the fatigue strength of polished steel specimens plated with nickel would be appreciably increased by plating until the retained residual compressive stress exceeds that induced by polishing. In the specimens tested (residual stress 6,000 p.s.i.) this condition probably did not obtain. Later experiments, conducted on coated steel in which the plating showed higher residual compressive stresses, lead, however, to the conclusion that with nickel coatings strongly bonded to the steel and showing residual compressive stresses of the order of 15,000-20,000 p.s.i. it should be possible to obtain appreciably improved fatigue properties. The author records tests indicating that the fatigue resistance of chromium-plated steel specimens can be materially improved by inducing a compressive-stress condition in the steel by peening *prior to plating*, although the properties are still inferior to those of the uncoated steel. A further graph shows the very marked increase in fatigue strength which is produced by peening of nickel-plated steel *after plating*.

It is observed that in some cases it may be found desirable to pre-stress by superficial rolling rather than by shot-peening, obtaining by this means all the benefits of residual compressive stresses, without risk of the roughening of surface liable to occur during shot-peening.

NON-FERROUS ALLOYS

Nickel and Nickel-Alloy Pipe and Tubing

INTERNATIONAL NICKEL CO., INC.: 'Fabrication and Design of Nickel and High-Nickel Alloy Pipe and Tubing.' *Tech. Bull. T.* 17 (*revised*), 1951; 26 pp.

The information contained in this bulletin refers specifically to seamless tubing which has been processed under controlled conditions. Welded tubing, welded-and-drawn tubing, and large-size, cold-drawn seamless tubing are *not* included, since their properties depend upon methods of manufacture, and may or may not conform to the limits given in this publication.

The materials covered are Monel, 'K' Monel, nickel, low-carbon nickel, and Inconel: typical compositions and physical constants for these materials are given, together with tables showing the average range of properties obtainable in tubing of various sizes.

The general introductory section includes details of the A.S.M.E. maximum allowable design stresses for nickel, Monel and Inconel, with discussion of methods for calculation of bursting and collapsing strength of tubing, to meet the requirements of the A.S.M.E. Boiler Code and other purposes. Methods for expanding condenser and heat-exchanger tubing are described, and notes are given on Van Stone flanging, hand threading and pipe threading.

Pipes and tubes of the three materials may be readily joined, to themselves or to headers, flanges and fitting, by metal-arc, oxyacetylene or inert-gas metal-arc welding methods, or by silver- or copper-brazing or soft soldering. Detailed recommendations are made for procedures to be used.

Bending and coiling methods are discussed, covering cold-bending, with or without an inside mandrel or filler, and in connexion with the use of low-melting point fillers of the Cerro-alloy and related types, methods of inserting the filler materials into the tubing are described. Recommendations are also made on press-bending and hot-bending methods: the latter method should, it is suggested, be avoided whenever possible, and where it is imperative that it should be used, strict control must be exercized with regard to the use of a sulphur-free sand. Heating procedure suitable for hot-bending operations is described.

In connexion with the use of nickel and nickel-alloy pipe and tubing at elevated temperatures, particulars are given of tensile and creep values characteristic of wrought Monel, nickel, low-carbon nickel, and Inconel, in the annealed condition, over a range of temperatures.

Attention is also directed to cast fittings now being produced in nickel and high-nickel alloys; typical mechanical properties are listed.

Appendices contain notes on available forms of tubing, tolerances for various forms of tubing, and U.S. specifications covering nickel and nickel-alloy tubing and pipe and the relevant welding and cast materials.

Resistance Welding of Nickel and Nickel-base Alloys

INTERNATIONAL NICKEL CO., INC.: 'Resistance Welding of Nickel and High-Nickel Alloys.' *Tech. Bull. T.* 33, 1951; 29 pp.

See also reprint in *Welding Jnl.*, 1951, vol. 41, Aug., pp. 685-710.

This publication contains a comprehensive discussion of the following welding processes, as applicable to nickel and nickel-base alloys:—spot, seam, projection and flash welding, and resistance brazing. The materials considered are Monel and 'K' Monel, nickel (wrought), low-carbon nickel, Duranickel (age-hardening type), Inconel (wrought), and Inconel 'X'. Compositions and mechanical and physical properties of the respective metals and alloys are shown (in comparison with those of carbon steel, stainless steels, aluminium alloy and copper), as a background for discussion of their welding characteristics.

The use of each of the processes, on some or all of the nickel-containing materials mentioned, is described in detail: design of joints, equipment required, welding procedure, defects liable to occur in the welds, and tests which may be used to determine the quality of the welds made. In each section the diagrams and other illustrations, together with the practical recommendations made, cover every aspect of the subject from an essentially practical point of view, and the publication forms a reference handbook, within the scope indicated.

Grading of Scrap Nickel Silver

C. GOLDBERG and T. DOBBINS: 'Note on the Grading of Scrap Nickel Silver.' *Chemist Analyst*, 1951, vol. 40, June, p. 38.

In an earlier communication (*ibid.*, 1950, vol. 39, p. 56: *Nickel Bulletin*, 1950, vol. 23, No. 12, p. 225) GOLDBERG proposed a rapid photometric method for grading scrap nickel silver according to its nickel content. The method comprised decomposition of the sample with nitric acid, taking to fumes with perchloric acid, addition of hydrochloric acid, and reduction of the blue cupric ions, to colourless cuprous ions, with sodium hypophosphite. Any precipitate due to the occasional presence of tin or silicon is filtered off, and the depth of colour of the nickel-chloride solution is measured.

Following a suggestion that treatment of the sample with hydrochloric acid and 30 per cent. hydrogen-peroxide solution would result in quicker determination, and avoid precipitation of metastannic acid, the following procedure has been developed:

'Transfer a 0·5 g. sample to a 50 ml. volumetric Pyrex flask and add 15 ml. of concentrated HCl. Place a small funnel in the neck of the flask and add 5 ml. of a 30 per cent. solution of hydrogen peroxide. Swirl the contents of the flask until the reaction becomes vigorous and then subsides. Now add, slowly and with swirling after each addition, 10 ml. more of the hydrogen-peroxide solution. The sample will now be completely decomposed. Wash the funnel with a little distilled water and remove it. After heating the flask gently to drive off the free chlorine, wash down

the sides and add 2·0 g. sodium hypophosphite, N.F. Swirl several times to dissolve the white precipitate and then cool under the tap to room temperature. Dilute to the mark with distilled water, stopper and mix well. If any silica is present, filter through a dry, fine filter paper into the absorption cell and measure the colour of the solution at 650 millimicrons.'

Nickel Silver Zip-Fastener Wire

H. H. SYMONDS: "Zip Fastener Wire.' *Metal Industry*, 1951, vol. 79, Aug. 10, p. 110.

This note reports an investigation of small zip segments which had been found to be liable to break in the region in which they were attached to the backing cloth. The specimens examined comprised a length of typical zip fastener, a sample of English nickel silver wire currently being produced for this purpose, returned material of American origin, returned material of English origin, and three samples of flattened wire, one of which was American.

Examination included determination of hardness, measurement of grain size, measurement of the size of the wires, and chemical analysis; full particulars of the results are given.

Failure (which had occurred in the English material only) is considered to have been mainly due to excessive hardness, which was closely related to its very high iron content (0·28 per cent.); in the American material this element was at a desirably low level (0·03 per cent.). The English wire conformed to the specification with regard to copper and nickel limits, while the American wire did not, but the non-compliance had resulted in a softer material, and had thus been in some sense beneficial. It is considered that an additional annealing operation would permit use of existing stocks of English wire.

A specific type of defect found in the English wire is believed to have originated in an oxidized cavity in the cast wire which was subsequently elongated during drawing. The condition of the zip fastener was in itself conducive to cracking on the side sections, due to undercutting during stamping.

Production, Consumption and Future Prospects of Nickel and Cobalt

See abstract on p. 189.

Conservation of Nickel: U.S. Orders

See abstract on p. 188.

Nickel Additions to Copper-base Alloys

J. S. VANICK: 'The Ni-Vee Bronzes, Parts I and II.'
'Nickel-Alloyed Manganese Bronze.'
Reprints from *Foundry*, 1951, vol. 79, Feb., pp. 102-7; Apr., pp. 130-3, 278-9; June, pp. 122-5, 226, 228.

Issued by International Nickel Co., Inc., 1951.

For abstracts of these papers see *Nickel Bulletin*, 1951, vol. 24, Nos. 4, 6 and 8, pp. 77, 133, and 174.

(Reference to reprints of the earlier parts of this six-part series will be found in *Nickel Bulletin*, 1951, vol. 24, No. 4, p. 55.)

Magnetostriction of Nickel and Nickel Alloys at Low Temperatures

See abstract on p. 189.

Copper Alloys containing Nickel: Compositions and Properties

COPPER DEVELOPMENT ASSOCN.: Classification of Copper and Copper Alloys.' *C.D.A. Publn.* 36: revised and amplified form: issued 1951.

This publication was first prepared during the early part of the 1939-45 war, to meet the desire of engineer-users and designers for concise tabulated data on the more common copper-base materials. The revised form includes information on specifications which have been issued since that date.

The material is presented in the form of tables giving typical compositions, relevant British Standard or other British specifications, typical mechanical properties, and general notes on the characteristics and uses of the respective metals and alloys. The classification covers raw copper, wrought special copper alloys (including those used for conductivity applications); brasses (strip, sheet, plate, tube, rods and sections); brasses and manganese bronzes (cast); brasses (wire); aluminium bronzes in various forms; phosphor bronzes and gunmetals (cast and wrought); copper-lead bearings; nickel silvers (wrought); copper-nickel alloys (wrought); silicon bronzes; welding, brazing and soldering materials.

Modulated Structures in Copper-Nickel-Iron Alloys

M. E. HARGREAVES: 'Modulated Structures in Some Copper-Nickel-Iron Alloys.' *Acta Crystallographica*, 1951, vol. 4, July, pp. 301-9.

The paper is concerned with alloys lying in the field marked 'metastable states' in the diagram given by BRADLEY, COX and GOLDSCHMIDT in 1941 for slowly cooled alloys. This lies at the extremity of the solid-solubility gap in the face-centred-cubic solid solution and in it the tie lines correspond to approximately constant Ni:Fe ratios. Separation of the two equilibrium (face-centred-cubic) phases involves, chiefly, diffusion of copper atoms. Following a review of earlier relevant literature, the authors report experimental observations made, in most cases, on an alloy containing copper 49·6, nickel 35·2, iron 15·2 at. per cent., i.e., approximately $Cu_{10}Ni_7Fe_3$, deoxidized with manganese.

The observations made indicate that X-ray diffraction effects in the copper-nickel-iron alloys studied can be accounted for qualitatively by considering the structure to be made up of a regular arrangement of lamellæ of the tetragonal intermediate phases, which form on annealing, but retain their coherence with the cubic crystal, and modulate it. Subsequently the tetragonal phases lose coherence with the matrix crystal and later transform to the cubic equilibrium phases. Satisfactory quantitative agreement between theory and experimental observation was obtained. The modulation of the matrix crystal takes place in the directions of the cube axes and is predominantly one of lattice parameter. The author's interpretation differs from

that advanced by DANIEL and LIPSON, which is discussed.

The limited amount of evidence at present available indicates that the magnetic properties of the copper-nickel-iron alloys are affected systematically by the development of the modulated structure, and it is considered that the property of permanent-magnetism may be intimately connected with the modulated structure both in these alloys and in copper-nickel-cobalt alloys, in which it is also found. Permanent-magnet alloys of the Alcomax type have also shown some evidence of the existence of a modulated structure.

The relation between the diffraction patterns of the modulated structures and those which arise from the independent particles of the intermediate phases is discussed, and the possible relevance of this relation to the interpretation of the diffraction patterns of alloys of the age-hardening type is indicated.

Silver Plating of Inconel

See abstract on p. 192.

Magnetic Properties of Binary Nickel Alloys

J. J. WENT: 'The Value of the Spontaneous Magnetization of Binary Nickel Alloys as a Function of Temperature.' *Physica*, 1951, vol. 17, June, pp. 596-602.

Measurements on alloys containing copper (up to 28 per cent), palladium (up to 20 per cent.), cobalt (up to 30 per cent.), iron (up to 25 per cent.), manganese (up to 12 per cent.), chromium (up to 4 per cent), molybdenum (up to 5 per cent.), tungsten (up to 5 per cent.), vanadium (up to 7 per cent.), aluminium (up to 15 per cent.), silicon (up to 8 per cent.).

The curve showing spontaneous magnetization vs. temperature for pure nickel is more concave towards the axis than that for any of the binary alloys studied, with one exception, that of completely ordered alloys such as slowly cooled Ni_3Fe. Explanations for the observed characteristics of the alloys are suggested.

Nickel in Aluminium-base Alloys

D. C. G. LEES: 'Effect of Alloying Elements on Corrosion-Resistance of Casting Alloys.' *Light Metals*, 1951, vol. 14, Sept., pp. 494-502.

The increasing use of aluminium-base castings in building and general engineering indicates that their mechanical properties and resistance to many forms of environment are satisfactory. Accurate knowledge of the corrosion-resisting characteristics of these alloys is, however, sparse, and this article has been written to summarize existing knowledge on the subject.

In connexion with the influence of alloying elements on corrosion-resistance, the following are considered: silicon, copper, magnesium, zinc, iron, manganese, nickel, titanium, niobium, tin and lead.

Nickel is an important constituent in aluminium casting alloys such as 'Y' alloy and the 'R.R.' series, e.g., in applications in which their improved mechanical properties at elevated temperatures are utilized. Little reliable information is available with regard to the influence of nickel on corrosion-resistance, and the data which do exist do not indicate any beneficial effect from the presence of nickel in this type of alloy.

Later sections of the review cover behaviour of alloys containing silicon, magnesium and copper, under natural atmospheric and under marine conditions; also the corrosion-resisting qualities of complex alloys.

NICKEL-IRON ALLOYS

Physical Properties of Nickel-Iron Alloys

MOND NICKEL CO. LTD.: 'The Physical Properties of the Nickel-Iron Alloys.' *Publn.* 431*, 1951; 23 pp.

This publication is to be regarded as a companion to No. 369, which deals with the magnetic properties of the nickel-iron alloys. It opens with a historical survey of the early work on nickel-iron alloys, with particular reference to the investigations of GUILLAUME, which revealed the unusual thermal expansion characteristics of certain alloys in this system. This is followed by a consideration of the nickel-iron constitutional diagram, and a systematic review of the properties of the alloys: mechanical properties, corrosion-resisting characteristics, electrical, and thermal properties are discussed.

The second section is concerned with dilatational properties. A series of curves illustrates the thermal expansion of binary nickel-iron alloys, and the influence of addition elements on coefficient of expansion is illustrated. In this connexion particular attention is directed to the properties of alloys containing 36, 42 and 48 per cent. of nickel: these are shown in comparison with the expansion values of some other materials. Methods of ensuring dimensional stability in nickel-iron alloys are described, with special reference to the 36 per cent. nickel alloy (Invar), which is extensively used in precision mechanisms. Typical applications of this material are in metrological standards; horological components; equalization of the expansion of two engineering components, thus minimizing temperature stresses; expansion control in aluminium-alloy pistons, and bimetals for temperature control. Reference is also made to other nickel-iron alloys which have special expansion characteristics, e.g., the 42 per cent. nickel alloy used in thermostats, and the alloys containing 46-50 per cent. of nickel, which are employed in glass-to-metal seals.

The publication also covers ternary nickel-iron-base alloys :— those of the nickel-cobalt-iron type which are of major importance for glass-to-metal seals, and another modification, used for a similar purpose, in which about 6 per cent. of chromium is added.

The final section deals with alloys of constant elastic modulus. The story of their development is traced from the observation by GUILLAUME, of the properties of Elinvar (36 per cent. nickel nickel-iron alloy containing about 12 per cent. chromium), mention being made of improved alloys of that type which have since been developed to give, for example, precipitation-hardening and other useful properties. In this connexion outstanding improvements have recently resulted from the development of nickel-iron

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titanium alloys, which are produced under the designation of 'Ni-Span' alloys. These materials show improved fabricating qualities, as compared with earlier alloys of the Elinvar type, and are characterized by superior strength and hardness, in conjunction with the requisite expansion and/or thermoelastic properties. Typical properties of this series are described, and applications are indicated. These include hairsprings for watches, diaphragm and Bourdon-tube gauge devices, electrically maintained tuning forks and other frequency-standard devices. Passing reference is also made to applications in which use may be made of the magnetostrictive properties of alloys of the nickel-iron series.

Conservation of Nickel: U.S. Orders

See abstract on p. 188.

Properties of Nickel-containing and other Ferrites

E. BOTH: 'Ferrite Materials Permit Improved Designs of Magnetic Devices.' *Materials and Methods*, 1951, vol. 34, July, pp. 76-9.

A general review of the properties and uses of typical ferrites, which occupy a position intermediate between two conventional magnetic materials, at frequencies in the audio- to radio-frequency range. The ferrites provide smaller eddy-current losses than laminated materials, and give higher permeability than powder cores.

Curves showing permeability and other characteristics of the nickel-zinc and other forms of ferrite are reproduced from the literature, e.g., from the paper by HARVEY *et al.* (*R.C.A. Rev.*, 1950, vol. 11, Sept., pp. 321-63; *Nickel Bulletin*, 1951, vol. 24, No. 1, p. 10). Typical uses of ferrite cores are illustrated, and the importance of correct design, in the utilization of such cores, is emphasized.

Nickel-containing Permanent-Magnet Alloys

K. HOSELITZ: 'Recent Progress in the Field of Permanent Magnets.' *Jnl. de Physique et le Radium*, 1951, vol. 12, Mar., pp. 448-57; disc., pp. 457-8.

A brief introductory note on the properties required in permanent magnets is followed by a detailed review of the characteristics of permanent-magnet materials developed during recent years. The survey is made in three main sections, covering, respectively, *precipitation-hardening alloys* (iron-cobalt-molybdenum, iron-nickel-copper, and iron-cobalt-vanadium); *diffusion-hardening alloys* (based on iron-nickel-aluminium, with additions of one or more of the elements cobalt, copper, titanium, niobium); *powder magnets* (e.g., Vectolite, Caslox, and other oxide types, and complex nickel-aluminium-iron powder materials).

Alnico Magnets in Velocity Meters

T. A. PERLS and E. BUCHMANN: 'A Bar-Magnet Velocity Meter.' *Rev. Scientific Instruments*, 1951, vol. 22, July, pp. 475-81.

The principle of the bar-magnet meter described consists in the generation of a velocity-dependent voltage by the motion of a long bar magnet relative to a long coil. The meter is claimed to have characteristics which make it highly suitable for measurement of vibratory and shock motions, and applicable in the solution of many problems arising in such measurements.

Experiments made with hardened tool steel, various grades of Alnico, and Cunife demonstrate that Alnico V combines all the features most useful in the magnet material. Methods for installing the velocity meter are also discussed.

Magnetic Properties of Binary Nickel Alloys

See abstract on p. 196.

Magnetostriction of Nickel and Nickel Alloys at Low Temperatures

See abstract on p. 189.

Modulated Structures in Copper-Nickel-Iron Alloys

See abstract on p. 195.

CAST IRON

Nickel-Alloy Cast Irons: Properties and Uses

INTERNATIONAL NICKEL CO., INC.: 'Nickel-Alloyed Cast Irons: Guide to the Selection of Engineering Irons.' *Publn. issued* 1951; 27 pp.

This bulletin has been compiled primarily for design engineers; it presents the many useful characteristics of modern types of alloyed cast irons, and illustrates some of their applications in large-scale industry.

An introductory note summarizes the modifications which are effected in the properties of cast iron by the addition of varying percentages of nickel, and lists the properties typical of engineering grades of alloy iron which are currently in general use.

Design factors are discussed in relation to use of alloy cast irons, e.g., higher uniformity and lessened section sensitivity, correlation of the properties of castings with those of test bars, and pattern design. Specifications are reviewed, with notes on methods of testing, and the nature of the specifications which should be laid down for cast irons to be used in various applications are tabulated.

As a background to the more fundamental consideration of the nature and properties of cast irons, the essential character of the material is considered in some detail, with a useful series of photomicrographs illustrating the types of structure characteristic of irons of various grades. This is followed by a comprehensive review of the mechanical properties obtainable in the different types (tensile strength, modulus of elasticity, compressive strength, transverse strength and deflection, shear and torsional strength, modulus of rigidity, impact strength, endurance limit and notch sensitivity, damping capacity, hardness, properties at elevated and at sub-zero temperatures, resistance to wear and to galling, and corrosion-resistance). The physical properties are also reviewed:—electric and

magnetic properties, thermal properties, and specific gravity.

The final sections deal with machinability, welding, and heat-treatment (quenching-and-tempering, surface-hardening, and stress-relief treatment).

The publication is illustrated throughout with photographs of parts for which cast iron has proved particularly suitable, due to one or more of the properties described in the text.

Nickel-Alloy Cast Iron in Crankshafts

A. B. EVEREST: 'Cast Iron Crankshafts, with Special Reference to Acicular and Spheroidal-Graphite Cast Irons.'* *Reprint of paper to Congrès International des Moteurs, Paris,* May, 1951.

Issued by Mond Nickel Co., Ltd., 1951; 20 pp.

For abstract of this paper see *Nickel Bulletin,* 1951, vol. 24, No. 6, p. 137.

Nickel-Alloy Steels and Cast Irons in Machine Tools

See abstract on p. 203.

Ductile Cast Iron Grate Bars

'Ductile Iron Makes Good in Sintering Grates.' *Nickel Topics,* 1951, vol. 4, No. 5, p. 2.

A comparative test on ductile cast iron and grey cast iron bars in a Greenawalt sintering furnace was initiated in August, 1950, and to date of reporting in June, 1951 no grates of the ductile iron had required replacement, although grates of grey iron had failed after 6 weeks' service. The performance of the ductile iron was also superior to that of steel grates previously tested.

Reference is also made to some other applications for which ductile iron appears to have a promising future. These include gears and clutches on farm implements, hatch-cover clamps for ships, and spacers for rope and chain falls. In the last-named application the ductile iron is replacing steel forgings, and its use has effected appreciable economy.

A further report on the successful use of the new iron for gears is made from a large foundry in Italy, where demand for castings of the new iron has been so great that a new building is to be devoted exclusively to this type of product.

Spheroidal-Graphite Cast Iron in Agricultural Equipment

H. L. GEIGER and H. W. NORTHRUP: 'A New Metal for Farm Tool Components.' *Reprint of paper from Agricultural Engineering,* 1951, vol. 32, Mar., pp. 143-7.

Issued by International Nickel Co., Inc.

The authors present a summary of information on the composition, processing and properties of magnesium-treated cast irons containing graphite in the spheroidal form. Specifications which have been set up by The International Nickel Company for the respective grades of spheroidal-graphite cast iron are given, and service records indicate the uniformity obtainable.

Pattern shrinkage is discussed, vis-à-vis that of ordinary grey cast iron, and a review is made of tests of wear-resistance, hardness and strength, which are of particular interest in connexion with use of the new irons in agricultural implements. Data on modulus of elasticity, mechanical properties vs. section, impact-resistance, and resistance to galling are also presented. In connexion with parts in which a high degree of wear-resistance is required, attention is called to the satisfactory response of spheroidal-graphite cast irons to flame-hardening; surface hardnesses of the order of 600 can be so produced in the as-cast iron, and 540 in the annealed material.

The spheroidal-graphite cast irons can be welded by procedure closely similar to that employed for ordinary grey cast iron: a welding rod designated 'Ni-Rod 55' is especially suitable for the purpose. A further advantage of the spheroidal-graphite irons is their improved machining characteristics, which have recently been established by an extensive series of tests: for details see abstract in *Nickel Bulletin,* 1951, vol. 24, No. 6, p. 136. Extracts from the report of these investigations are included in the present paper.

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CONSTRUCTIONAL STEELS

Hot-Tearing in Nickel-Alloy Steels

J. M. MIDDLETON and H. T. PROTHEROE: 'The Hot-Tearing of Steel.' *Jnl. Iron and Steel Inst.,* 1951, vol. 168, July, pp. 384-98. (British Iron and Steel Research Association Paper SC/A/11/51).

The paper opens with a description of apparatus devised for determining the loads which a steel will withstand before tearing at high temperatures. Using this equipment, a study was made of the effects of casting temperature, and of the influence of composition, on resistance to tearing. It is shown that hot-tearing is more likely to occur, and is more severe, at high than at low casting temperatures. Of the elements investigated (carbon, silicon, manganese, sulphur, nickel, chromium, copper, phosphorus, molybdenum, titanium, vanadium) sulphur is the most injurious: even small amounts result in lowered tearing resistance. The most beneficial elements are titanium and vanadium. The effect of nickel up to 2·4 per cent. was to reduce tearing-resistance at all casting temperatures: with further increase up to 3·5 per cent. no further lowering of resistance was observed, and for some casting temperatures there was a slight improvement with the increase of alloy content. A nickel-chromium steel (2·4/0·93 per cent.) showed better tear-resistance than the plain nickel steel.

Later sections of the paper deal with the effect of deoxidation with aluminium, on tear-resistance, and with the hot-tearing susceptibility of killed and semi-killed steels. An appendix contains a statistical analysis of hot-tear tests.

Conservation of Nickel: U.S. Orders

See abstract on p. 188.

Mechanical Properties of Nickel-Alloy Steels

MOND NICKEL CO., LTD.: 'The Mechanical Properties of Nickel Alloy Steels.' *Publn.* 468,* 1951; 84 pp.

This handbook summarizes the mechanical properties of representative heat-treatable steels in current use: it is intended to provide a source of reference for engineers, designers, metallurgists, and heat-treatment superintendents.

The steels discussed are those used in (1) the hardened-and-tempered, or (2) the case-hardened condition. The types chosen have been selected from B.S. 970, 1947, 'Wrought Steels for Use up to 6-in. Ruling Section, for Automobile and General-Engineering Purposes'. The steels are dealt with in two main groups:

Direct-Hardening: covering En 10, 12, 13, 21, 22, 23, 24, 25, 26, 27, 28, 30A, 30B, 100, 110, 111, 160. In this section particulars are also given of the high-tensile corrosion-resisting steels to En 57.

Case-Hardening: covering En 33, 34, 35, 36, 37, 38, 39A, 39B, 320 and 325 carburizing types, and D.T.D. 228 and B.A.C.E. 165 nitriding steels.

For each steel details are given of relevant specification limits for composition, heat-treatment, and mechanical properties; representative test values (which include the effect of mass), and tempering diagrams (for the direct-hardening steels only).

In comparison with the earlier Mond publication on mechanical properties of nickel-alloy steels (A.11), two main modifications have been made:—(1) the effect of size is now taken into consideration, and the value for 0·1 per cent. proof stress has been substituted for elastic limit. The additional usefulness of data so modified is discussed in the introduction.

Further information of a reference character included in appendices is indicated below.

Miscellaneous Physical Properties of a 3 per cent. Nickel Nickel-Chromium Steel (En 23 type).

Heat-treated Nickel-Alloy Steels for Aircraft. The B.S. 'S' series, which have recently been revised and now conform fairly closely to certain of the En steels. Data on composition, heat-treatment and properties.

Relationships between Specified Tensile Strength and other Mechanical Properties: for sheet and strip; tubes; bars, forgings and rods.

Automobile Nickel-Alloy Steels, as laid down in B.S. Handbook No. 8, 1948 edition.

Conversion Table showing Rectangular Sections and Plates to Equivalent Rounds.

Tabular Comparison of En Steels with other Official Specifications (including reference to specifications issued by various British standardizing bodies, those published by the Society of Automotive Engineers, and the Swedish S.I.S. series).

Miscellaneous Mechanical Properties of Nickel-Alloy Steels, including data on effect of tempering on case-hardness; influence of sub-zero treatment on case-hardness; average values for elastic moduli of nickel-alloy steels; torsion-test data, and notes on fatigue properties and the effect of surface condition on fatigue-resistance.

Conversion Tables showing Hardness/Tensile Strength Relationships.

Comparison of various Official Tensile and Impact Test Pieces as standardized in Britain, European countries and the U.S.A.

Corrections to be applied to Elongation for Variations in Reduction of Area, and *Relationships between Izod and Charpy Impact-test results.*

* *We shall be pleased to supply a free copy of this publication.*

Sub-Zero Properties of Metals and Alloys

'Properties of Metals Used at Low Temperatures.' *Metal Progress,* 1951, vol. 60, July, pp. 79-80, 108, 110, 114, 116, 118.

Brief notes on papers and discussion presented at a symposium on 'Influence of Low Temperatures on the Mechanical Properties of Metals', convened by the National Bureau of Standards in connexion with its semi-centennial celebrations. The subjects and authors of the papers are shown below.

R. L. SMITH *et al.* 'Low-Temperature Tensile Properties of High-Purity Iron-Carbon Alloys.'

M. WILLIAMS: 'Brittle Fractures in Ship Plates.'

J. B. AUSTIN: 'The Manufacture of Steels for Low-Temperature Service.'

N. P. ALLEN: 'Theoretical Considerations on Low-Temperature Effects on Metals.'

D. A. SHINN and J. B. JOHNSON: 'Application of Metals in Aircraft at Low-Temperatures.'

V. N. KRIVOBOK: 'The Properties of Austenitic Stainless Steel at Low-Temperatures.'

This paper included data on the effect of composition, heat-treatment and cold-working, on the properties of high-alloy nickel-chromium steels, particular attention being directed to the beneficial influence of extra-low carbon content. Experimental data on modulus of elasticity, fatigue, impact, tensile-impact and other properties were summarized and critically appraised. Attention was directed to the high ductility values obtained for notched bars of 18-8 steels at sub-zero temperatures.

W. CRAFTS AND C. M. OFFENHAUER: 'Low-Temperature Properties of Low-Alloy Chromium-Copper-Nickel Steel.'

The steel discussed had the following composition: carbon 0·12 max., manganese 0·65-0·85, silicon 0·15-0·25, copper 0·40-0·60, nickel 0·50-0·75, chromium 0·65-0·85, per cent. Such steel is reported to show a fair degree of resistance to atmospheric corrosion, to be readily weldable, and to have given good service for over 15 years in several installations operating at temperatures as low as −80°C. (−112°F.). Recent studies have indicated that the steel may retain a good degree of toughness even at −100°C. (−148°F.). Retention of toughness to this temperature is closely dependent on maintenance of suitable structure: appearance of a 'pseudo-martensitic' structure is associated with deterioration in sub-zero strength. Close control of the balance and amount of carbide- and austenite-forming elements is essential, and a certain minimum aluminium content is desirable, to maintain fine grain size and to inhibit formation of the non-pearlitic structure.

C. W. MACGREGOR and N. GROSSMAN: 'Dimensional and Design Effects of Test Specimens: Effect on Fracture Characteristics.'

G. W. GEIL and N. L. CARWILE: 'Tensile Properties of Copper, Nickel, and Some Copper-Nickel Alloys at Low Temperatures.'

This paper contained tensile data, over the range 100° to −196°C. (212° to −320°F.), for high-purity copper and nickel, and for 70-30 and 30-70 copper-nickel alloys, in the annealed conditions. It was observed that the 'rim effect' (contraction of the specimens at the base of the neck during actual fracture) was considerable and tended to decrease as the temperatures were lowered. Because of this rim effect, accurate values of the true stress (σ) and strain (δ) at fracture can be determined only from measurements made at the initiation of fracture. The true stress-strain tension data did not conform to the commonly accepted parabolic relationship $\sigma = k\delta^m$, but the strength indexes, as represented by the initial strength, nominal ultimate stress, true stress at maximum load and true stress at initial fracture, increased continuously with decrease in temperature within the range studied. The uniform strain (true strain at maximum load) generally increased with decrease in test temperature, but no general trend was indicated in the slight variation of total strain (true strain at initial fracture) with temperature. The rates of work-hardening at specific true strain, in general, increased continuously with decreased temperatures. For small true strains, the increase in the rate of work-hardening of the cupro-nickel and the 70 per cent. nickel, 30 per cent. copper alloy with decrease in temperature was less than that of either the copper or nickel, but for larger true strains (greater than 0·2), the work-hardening rates were greater for the alloys.

NOTE. The titles assigned to the papers in the above notes have been, in some cases, deduced from the nature of the information given: they do not necessarily correspond exactly with the authors' titles, under which full versions of the papers may later appear.

Notched-Bar Tests on Nickel-Alloy Steels: Influence of Sharpness of Notch

N. A. KAHN, E. A. IMBEMBO and F. GINSBERG: 'Effect of Variations in Notch Acuity on the Behaviour of Steel in the Charpy Notched-Bar Test.' *Proc. Amer. Soc. Testing Materials*, 1950, vol. 50, pp. 619-47; disc., pp. 647-8.

The authors present a critical summary of data on the effects of small variations in notch-root radius of Charpy V- and keyhole-type specimens, on the energy-absorption level and location of the transition-temperature region of a number of steels. The principal objective of the work reported was to establish tolerances for the root-radius dimension of the V-notch, for which at present no standards exist.

The materials used in the investigation comprised some U.S. Navy medium- and high-tensile steels, S.A.E. 1045 carbon steel, and S.A.E. 4620 nickel-molybdenum steel, heat-treated to tensile-strength levels of approximately 60,000, 70,000, 85,000, 110,000 or 155,000 p.s.i. (27, 31, 38, 49 or 69 tons per sq. in.).

For each steel and condition, energy-temperature relationships were established for V-notch radii of 0·006, 0·0075, 0·009, 0·010, 0·011, 0·012, 0·015, 0·017, and 0·021 in., and for keyhole diameters produced by Nos. 46, 47 and 48 drills. The effect of polishing the base of the standard A.S.T.M. 0·010-in. radius V notch was also investigated. Equipment and techniques for preparing the notches and for conducting the tests are described.

Influence of Electrodeposited Nickel Coatings on the Mechanical Properties and Fatigue-Resistance of Steel

See abstract on p. 193.

Thermal Conductivity of Nickel-containing Materials

J. DE NOBEL: 'Heat Conductivity of Steels and a Few Other Metals at Low Temperatures.' *Physica*, 1951, vol. 17, May, pp. 551-61.

Thermal-conductivity values, at various temperatures within the range 93·1° to 15·1°K. (−180° to −258°C.), were determined on a range of materials on which measurements of low-temperature properties had previously been made by SIR ROBERT HADFIELD (*Phil. Trans., Roy. Soc., Ser. A*, 1933, vol. 232, pp. 297-332). The materials investigated included aluminium, Duralumin, specially pure iron, nickel (99·4 per cent. purity), low- and high-alloy nickel-manganese steels, Era A.T.V. (high-carbon austenitic nickel-chromium-iron alloy), 31 and 36 per cent. nickel steels, high-manganese steel, chromium and chromium-nickel corrosion-resisting steels, and mild steel.

Influence of Boron in Steels; Properties of Boron-treated Steels

D. I. BROWN: 'Boron Steels. A New Era in Alloy Metallurgy.' *Iron Age*, 1951, vol. 168, July 5, pp. 79-85; July 12, pp. 85-90; July 19, pp. 102-6; July 26, pp. 68-72; Aug. 9, pp. 75-9.

The aim of this series is to present the latest information on boron-containing steels, with a critical appraisal, in the light of information so far available, of 'what they will do, what they won't do, and how they are being applied.'

Part I reviews the background of development of boron treatment, and lists the boron-containing types of steel which are being recommended as alternatives to some of the more-highly-alloyed standard grades. Ferro-alloys which may be used for introduction of boron are listed, the influence of boron on hardenability is demonstrated, and some of the general advantages and limitations of the boron-treated steels are reviewed.

Part II contains an evaluation of the carburizing grades 43B17 and 43B10, which are being used in some cases in place of 4820, 3310 and 9310 steels, e.g., in heavy-duty aircraft and truck applications. It is claimed that fatigue-resistance and durability of the boron-containing steels are better than those of the conventional types.

The boron through-hardening steels have been developed mainly on an equivalent-hardenability basis: this paper contains some comparisons between the new 'alternates' (80B00 and 94B00) and the 8600, 4100 and 4600 steels which they are, respectively, intended to replace.

Part III deals with the properties, treatment and applications of three grades of boron-containing carburizing steel which are stated to be already in use in considerable tonnage, the low-nickel-chromium-manganese-molybdenum grades 94B20 and 94B17, and the low triple-alloy 80B20. Test results quoted for these steels show that they have better wear- and fatigue-resistance than some of the more-highly-alloyed steels, and although the boron-containing grades distort more in heat-treatment, the distortion is consistent, and can be to some extent overcome by changes in design and heat-treatment methods. Typical data are cited for the properties of boron-treated steels after carburizing and after nitriding. Properties and applications are discussed, mainly in connexion with the use of the steels in gears: much of the information given is based on tests made by gear manufacturers.

Part IV describes the properties of the 50B00 steels, low-alloy chromium steels developed to replace the 4000 series. A considerable amount of data is given on the case-hardening characteristics and hardenability of this range of steels, which are being used, in various conditions, for gears, bolts, leaf springs and other purposes. The 50B00 series has been adopted by the American Iron and Steel Institute in its tentative-standard grading. This instalment also contains information on some of the 4000 steels. (A useful list of earlier articles on boron-containing steels is included in this section of the review).

Part V describes the application of carbon-boron steels for bolts and hand tools: hardenability characteristics of such steels are discussed, and the carburizing characteristics of 14B20 steel are compared with those of the standard 8620 grade. A particularly promising steel of the 14B00 series is the 14B45 grade, which has shown especially good spring properties.

One of the most generally used medium-carbon boron-treated alloy steels, the 86B45, is also discussed. This grade has been used for highly stressed axle shafts, spindles and similar parts, and the steel is claimed to have certain advantages over the 4340 type formerly used. Heat-treatment of this steel for production of good machining properties is discussed, and the characteristics of 81B45 steels are also considered.

The series has been reprinted in a 32-page booklet, which is available from *Iron Age*, 100 E. 42nd Street, New York 17, N.Y.

'Boron Steel.'
Metal Progress, 1951, vol. 60, Aug., pp. 81-92.

This is a report of the Metallurgical Advisory Board organized at the request of the Research and Development Board, by the National Academy of Sciences, National Research Council, to advise the Research and Development Board of the Department of Defense on research aspects of critical problems facing the U.S.A. in relation to metals.

In view of the widespread activity in making and testing of boron-containing steels, the Committee has considered it desirable to bring together in one place pertinent data and findings on this subject. The purpose of the recent report is to provide a factual summary of steel-making practices, applications and properties, which can be used as a reference for furthering the applications of the boron steels and thereby conserving critical alloys. The information presented is based on a comprehensive survey of the literature, and on unpublished reports and communications made to the Committee by producers and users of boron-treated steels.

Sections of the report cover interchangeability of the boron-containing steels with higher-alloy steels, with a view to conservation; surface-hardening by induction as a means of saving strategic elements; the use of boron to this end, and the technique of making boron additions; composition of addition media by which boron is introduced; hardenability and other properties of boron-containing steels, in comparison with those of the higher-alloy steels which they are intended to replace; treatments recommended to produce optimum properties in the boron-treated steels, and the limitations of the boron-containing steels.

See also—

'Boron and Alternate Steels.' *ibid.*, p. 80B: *Metal Progress Data Sheet.*

Lists issued by the American Iron and Steel Institute June 13, and July, 1951, giving compositions of 'interim alternate' or 'alternative standard' steels designed to conserve nickel and/or molybdenum.

P. R. WRAY: 'The Rôle of Boron Steels in the Present Emergency.' *Materials and Methods*, 1951, vol. 34, Aug., pp. 57-60.

This review of the potential usefulness of the boron-containing steels emphasizes the importance of their correct use, and the recognition of their limitations, if they are to be employed to fullest possible advantage. Consideration of the properties of the carburizing and the direct-hardening grades of boron-treated steels indicates that greater care must be exercized in their selection, than in choice of the more conventional alloy steels, due to the following factors:—

'(1) Hardenability must be adequate, so that a tempered martensitic structure is obtained at the location where the highest stresses are encountered. If other structures are obtained in heat-treatment, mechanical properties, particularly toughness, may be impaired to an even greater extent than in conventional alloy steels.

'(2) Boron exerts a pronounced effect on the hardening properties, but little or no effect in retarding softening at elevated temperatures. This usually necessitates a lowering of the tempering temperature to attain a desired hardness or strength.

'(3) Boron cannot perform the same function as molybdenum, vanadium or tungsten in contributing strength at elevated temperatures. Consequently, any attempt to replace steels high in these elements with boron steels for high-temperature applications is not considered practical.

'(4) Because of a decreasing hardenability effect of boron with increasing carbon content, the hardenability of the case of a carburized part may be insufficient. Some improvement can be effected by limiting the maximum carbon in the case to about 0·90 per cent. carbon.

'(5) Carburizing followed by direct quenching may decrease the hardenability of the core. Either delayed quenching (i.e., slow cooling to about 1550°F. (842°C.) prior to quenching) or double treatment seems to be an effective remedy.'

Several new series of boron alloy steels have been developed to conserve critically short alloys, and it is believed these steels will have fairly wide application.

See also fuller discussion by same author in *S.A.E. Jnl.*, 1951, vol. 59, July, pp. 46-52.

Surface Hardening of Steel

G. T. COLEGATE: 'The Surface Hardening of Steel. Part VI. Gas Carburizing.' *Metal Treatment and Drop Forging*, 1951, vol. 18, July, pp. 317-22.

For abstracts of previous instalments in this series, see *Nickel Bulletin*, 1951, vol. 24, Nos. 4, 5 and 8, pp. 84, 108 and 178-9.

Part VI deals principally with sooting, which is one of the main problems associated with gas carburizing.

Sooting takes place only when the rate at which carbon is produced at the surface of the steel is greater than that at which the steel can absorb it; the amount of sooting liable to occur depends on the composition of the carburizing gas, particularly on the amount of active agent present, and also on the diluent used. Methane shows less tendency to give sooting than do its higher homologues, and, from this point of view, carbon monoxide is to be preferred to atmospheres containing hydrocarbons.

Various methods have been devised to prevent sooting. The basic principles and main features of operation of the respective procedures are reviewed by the author. Reference is made to methods involving (1) reduction of the concentration of active gas to as low a value as is consistent with effective treatment, by means of additions of an inert or a decarburizing gas, (2) intermittent-surge action, involving alternating cycles of carburizing and soot-removal, (3) use of a three-zone furnace in which temperatures and gas-mixtures are adjusted to produce carburizing and soot-removal, (4) use of heated circulating gas to prevent soot formation, and (5) use of a rotating-retort furnace in which the purely mechanical action of the parts rubbing against each other is used to effect removal of soot.

Attention is also directed to the important effect, on carburization, of the rate of flow of the gases through the furnace. The advantages and disadvantages of high rates of flow and of turbulence are briefly considered.

The second section of Part VI reviews the gas-carburizing atmospheres which are in current commercial use in England and America. Advantages and limitations of the respective gases are indicated, with regard to the use of town's gas, natural gas, liquefied hydrocarbons, gas-generating solids, and various mixtures of gases. The diluents used are also considered, viz., air, propane, carbon dioxide, flue gas and similar mixtures, dissociated ammonia, charcoal-treated gas, etc.

A final section contains a short note on atmospheres specifically generated for gas carburizing, in which carbon monoxide is the active agent. Methods of generation are noted, together with the characteristics of the gases resulting from the respective methods of production.

As in other instalments in the series, the information given is supported by a useful *bibliography*.

'Part VII. Nitriding.' *ibid.*, Aug., pp. 363-8.

Nitriding is in some cases a competitor of carburizing, but in general each process has its well-defined fields of application. In this article the author attempts to indicate the similarities and the differences between the two processes, and the practical significance of such similarities and differences as affecting the uses to which they are put. A brief introductory note on the iron-nitrogen system shows the basic principle on which the nitriding process is founded.

The susceptibility of a steel to nitriding is largely determined by its composition, and in order to develop maximum hardening by this process it is necessary that there shall be present one or more elements which form stable nitrides insoluble in the iron below the temperature at which nitriding is carried out. Such nitrides are formed by chromium, vanadium, molybdenum and aluminium: the author summarizes the effects of the individual alloying elements, and refers to the influence of nickel, which is also present in some steels used for nitriding. Although nickel tends to reduce the hardness of the case obtainable by nitriding, it strengthens and toughens it, and the presence of nickel also ensures improved properties in the core, thus providing better support for the case. It also assists in development of dispersion hardening, in steels containing appreciable amounts of aluminium.

Three main classes of ferrous material are used for nitriding:—

(1) *the 'Nitralloy' steels*, containing chromium, aluminium and molybdenum in various combinations, with or without nickel or vanadium: typical compositions are tabulated;

(2) *stainless steels*, of both the nickel-chromium and straight-chromium grades;

(3) *cast irons*.

The individual characteristics of the respective types of material will be discussed later in this article, from the point of view of their susceptibility to nitriding and the properties obtainable in the treated products.

The closing sections of the present instalment contain a discussion of the conditioning of steel for nitriding and preparatory procedure, and a brief note on equipment used. Boxes in which the work is packed for treatment are usually made of heat-resisting steel or of Monel, and in many cases, easy circulation of the ammonia atmosphere is facilitated by separating the parts being treated into a number of layers, by means of nickel mesh.

Effect of Structure on Machinability of Nickel-Alloy Steels

N. ZLATIN and L. NOWIKOWSKI: 'Effect of Structure on Machinability Demonstrated.' *Iron Age*, 1951, vol. 168, Aug. 2, pp. 95-8.

Investigation of 3140 (nickel-chromium), 4140 (chromium-molybdenum) and 8640 (lean triple-alloy) steels shows that when heat-treated to similar structural condition the three steels have comparable machinability, demonstrating that microstructure is a safer criterion of machining quality than is composition. Structures of steels treated to give varying proportions of pearlite and free ferrite are illustrated, and curves show results of tool life in machining steels in the various conditions. The tests reported show that structural differences in the work machined are of less significance with carbide tools than with tools of high-speed steel.

Experiments with modified forms of the three steels indicate that resulphurizing to about 0·1 per cent. improves machinability.

Nickel-Alloy Steel in Airscrew Blades

'Steel Airscrew Blades. The De Havilland Composite Construction.' *Aircraft Production*, 1951, vol. 13, July, Aug., and Sept., pp. 202-8, 234-40, 268-75.

This series of articles gives a highly detailed description of the design and production of the de Havilland steel airscrew blade, which comprises a central load-carrying tubular core, surrounded by a shell of aerofoil section, to which it is attached by brazing. A rubber filling of low density is used for both core and shell. This type of construction has already been developed by the Hamilton Standard Division of United Aircraft Corporation, where large-scale production has reached the level of 1,000 blades or more per month. The two companies are associated in the development in England.

For the core tubes the material used is a high-tensile steel of the following composition: carbon 0·48, nickel 1·75, manganese 0·7, chromium 0·75, molybdenum 0·25, per cent.: the shell is made from a 1 per cent. chromium steel containing small amounts of nickel and molybdenum. A well-illustrated account is given of the various stages in production of the blades, including the brazing operations, and of methods used for inspection of the finished blades.

Nickel-Alloy Steels and Cast Irons in Machine Tools

G. R. BROPHY and W. S. MOUNCE: 'The Saga of Nickel in Machine Tools.' *Machinist*, 1951, vol. 95, Aug. 11, pp. 1203-6.

The year 1951 marks the 200th anniversary of two events: first, the birth of the machine-tool industry, by the construction, in France, of the first practical lathe; second, the isolation and identification of nickel by Cronstedt. This article shows how the two events are related, describing the many uses of nickel-containing steels and nickel-containing cast irons in machine tools of various types. The automobile industry formed the essential link, since experience there, of the valuable properties and many uses of nickel-containing materials, focused the attention of machine-tool makers on the potential value of such materials in that industry.

The article gives a historical survey of developments, from the discoveries of 1751, down to the types of steels and cast iron in use to-day.

HEAT- AND CORROSION-RESISTING MATERIALS

Effect of Rate of Strain on Properties of High-Temperature Alloys

M. J. MANJOINE: 'Effect of Rate of Strain on the Flow Stress of Gas Turbine Alloys at 1200° and 1500°F.' *Proc. Amer. Soc. Testing Materials*, 1950, vol. 50, pp. 931-48: disc. pp. 949-50.

In the gas turbine stationary parts are combined with others rotating at extremely high speeds: in operation, many of the parts are also subject to a range of loads and temperatures, and some may suffer impact. It is therefore imperative that the designer should be in possession of information, for the materials of construction, on rate of flow, ductility, and time-to-failure under given stresses and at given temperatures, or the maximum stress and strain which the material will withstand when deformed at various rates and temperatures.

In this paper the author has provided data along these lines. Ultimate tensile strength values are given for several gas-turbine alloys, at 1200° and 1500°F. (648° and 815°C.), for strain rates ranging from 10^{-7} to 10^{6} per hour.

Four wrought alloys and six precision-cast alloys were used in the investigations:—

Wrought: K 42B, type II; age-hardening Inconel; Nimonic 80; Refractaloy.

Cast: Stellites Nos. 21, 23, 27, 30, 31 and 6.

Full details of composition are given, and the four types of testing machine used to cover the range of strain rates mentioned are described.

Among the conclusions drawn from the experimental data recorded are the following:—

'The shape of the stress-strain curve at extremely rapid rates of strain at 1200° and 1500°F. for all the alloys is similar to that obtained at ordinary short-time tensile rates. In general, the materials under discussion strain-harden nearly up to fracture, i.e., the load increases with strain and the strain distribution is uniform practically up to fracture.

'In general, the ultimate tensile strength for wrought alloys at 1200°F. increases with rate of strain up to 10^{2} or 10^{3} per hour and then decreases. For the cast alloys at that temperature flow increases up to a rate of 10 per hour, decreases from that point slightly up to 10^{3} per hour, and then increases with increasing rate of strain. At 1500°F. (815°C.) the ultimate tensile strength of all the alloys increases with strain rate, and shows a slight dip at a rate of about 10^{3} per hour.

'At 1200°F., the cast alloys examined have lower strengths than the wrought types, except at the highest

rates of strain used. Relative superiority of the materials was found to depend on the rate of strain at which they were compared.

'At 1200°F., the elongation-at-fracture curve follows a pattern similar to that of the stress curve. At 1500°F., however, the elongation curve for some of the alloys is not so regular. Elongations at intermediate and at high rates of strain were found to be much greater than those obtained in the creep range of testing: in some cases the differences were as great as 100-fold.

'Desirable working speed for a given material at a given temperature can be estimated from the elongation and ultimate-tensile-strength curves, as a function of rate of strain. The desirable speed is near the peak of the elongation vs. strain-rate curve.'

Attention is drawn to the possible error introduced by use of rapid methods of sorting or comparing alloys for service in the creep range. It is pointed out, however, that such methods give accurate data for processes involving comparable rate of strain.

The author presents a characteristic flow-stress curve which qualitatively expresses variation in stress as a function of rate of strain, time to failure, or temperature. Such a characteristic curve is, in general, a family of curves for various strains: the family converges to a narrow band for the lower rates or for high temperatures. Factors which influence this characteristic curve are discussed: (1) strain; (2) rates of strain and loading, or time-to-failure; (3) temperature; (4) metallurgical state (as influenced by composition, prior processing and heat-treatment); and (5) state of stress.

Rate-Process Theory Applied to Iron-Cobalt-Chromium-Nickel Alloy

I. S. SERVI and N. J. GRANT: 'Creep and Stress Rupture as Rate Processes.' *Jnl. Inst. Metals*, 1951-52, vol. 80, pp. 33-7: *Advance Copy* 1322: *Monthly Jnl.*, Sept., 1951.

Creep data obtained on the alloy S.590* (reported by GRANT and BUCKLIN (*Trans. Amer. Soc. Metals*, 1950, vol. 42, pp. 720-51; *Nickel Bulletin*, 1949, vol. 21, No. 12, p. 201) are analyzed according to the rate-process theory of plastic flow. The data indicate that the theory can be applied over only a limited range of creep rates.

The authors propose an empirical equation for analysis of creep values: this relates the applied stress and the temperature to the minimum creep rate. Such an equation is valid only in the absence of structural instability.

Statistical Analysis of Stress-Rupture Data on S-816 Alloy

J. M. CAMERON and W. J. YOUDEN: 'The Selection of a Limited Number from Many Possible Conditioning Treatments for Alloys, to Achieve Best Coverage and Statistical Evaluation.' *Proc. Amer. Soc. Testing Materials*, 1950, vol. 50, pp. 951-60; disc. pp. 961-4.

During the 1939-1945 war the Allegheny-Ludlum Steel Corporation obtained stress-rupture data on over 200 specimens of S-816 alloy (typical composition: carbon 0·4, manganese 0·6, silicon 0·3, chromium 20, nickel 20, cobalt 45, molybdenum 3, tungsten 4, per cent., balance iron). Some 20 different treatments were used, with a view to producing materials in conditions satisfying particular production demands. These data have been examined statistically at the National Bureau of Standards, and the present report gives the results of the analysis. Although the paper is essentially concerned with the interpretation of the test results and the general problem of exploratory investigations and ways and means of facilitating statistical analysis, the tabular data on which the discussion is based are of interest in relation to the actual behaviour of the alloy.

Sigma Formation in Austenitic Nickel-Chromium Steel: Effect of Prior Treatment

G. V. SMITH, E. J. DULIS and H. S. LINK: 'Effect of Prior Treatment on Precipitation of Sigma Phase.' *Welding Jnl.*, 1951, vol. 30, Aug., Suppl. pp. 385-96.

Earlier papers by the same authors have reviewed the literature dealing with sigma phase and have reported experimental work on methods of identification of sigma (see *Iron Age*, 1950, vol. 166, Nov. 30, pp. 63-8; Dec. 7, pp. 127-32 and *A.S.T.M. Special Tech. Publn.* 110, 1951; abstracts in *Nickel Bulletin*, 1951, vol. 24, No. 2, p. 40, and 1950, vol. 23, Nos. 8-9, pp. 158-9).

This third paper describes work done to determine—(1) the effect of heating at 1700°, 1900°, 2100° or 2300°F. (925°, 1035°, 1150° or 1260°C.), followed by water quenching, air-cooling or furnace-cooling, on the microstructure and hardness of 18-8-Nb and 25-20 chromium-nickel steels which had previously been cold-drawn to about 40 per cent. reduction, and (2) the effect of such treatments on precipitation of sigma when the materials were subsequently exposed for periods up to 7,500 hours (313 days) at 1300°F. (705°C.).

It is pointed out that the influence of heating over the wide range used is of particular interest in connexion with weld heat-affected areas, and that the sigmatizing exposure temperature of 1300°F. is somewhat higher than any which has at present been employed commercially for steam-pipe service, but may be expected to give an approximate indication, in a relatively short time, of effects which would be produced in a longer time at a lower temperature.

The report gives much information on the experimental methods employed, and on the structure of the steels in various conditions. Photomicrographs and curves present a comprehensive survey of the effects produced by the various treatments.

The authors summarize their findings as follows:—

'*(A) Effect of Heating in the Range* 1700°-2300°F. (925°-1260°C.) *and of Rate of Cooling therefrom after Prior Cold Work*

'1. Both steels completely recrystallized on heating at 1700°F. or higher.

'2. The 25Cr-20Ni steel contained a relatively large amount, perhaps 10 per cent. of sigma, after cooling

* *Cobalt 20, chromium 20, nickel 20, tungsten 4, molybdenum 4, niobium 4, carbon 0·5, per cent., balance iron.*

from 1700°F., a very slight amount after cooling from 1900°F., but none after cooling from higher temperatures. Neither the quantity nor distribution of sigma changed significantly with the cooling rate from 1700°F., but for the 1900°F. level slower cooling yielded slightly more sigma. No sigma was observed in the 18Cr-8Ni-Nb steel after heating at 1700°-2300°F.

'3. With increase of heating temperature from 1700° to 2300°F., the carbides in either steel dissolved to an increasing extent. These were retained in solution on quenching, but again precipitated, preferentially at the grain boundaries, on air or furnace cooling. Carbides in 25Cr-20Ni steel completely dissolved at 2100°F. In the 18Cr-8Ni-Nb steel, particles, found to have the crystal structure of NbC or NbN, remained undissolved at the highest temperature, whereas small 'carbides' were completely dissolved at this, but not at lower, temperature.

'4. The grain size of each alloy became coarser and the hardness decreased as heating temperature increased. Except for the 25Cr-20Ni steel heated at 2100° and 2300°F., the hardness was little affected by rate of cooling; in these two instances, hardness decreased slightly with slower cooling.

'(*B*) *Effect of Time at* 1300°*F.* (705°*C.*)

'1. Regardless of prior treatment, both steels developed sigma during exposure at 1300°F. Carbide also precipitated to an extent dependent upon the amount retained in solution during prior treatment.

'2. The maximum amount of sigma observed in the 25Cr-20Ni steel was estimated to be 30 to 40 per cent.; considerably less was noted in the 18Cr-8Ni-Nb steel, the maximum being 5-10 per cent. Correspondingly, the hardness changes were less pronounced in the latter steel and were no doubt much more influenced by carbide precipitation and agglomeration.

'3. In 25Cr-20Ni steel previously heated to 1700°-1900°F., the quantity of sigma developed at 1300°F. appears, from both microscopic and hardness examination, to have attained nearly its maximum value, some 30-40 per cent., when sigmatized for 1000 hours, the shortest interval studied. After prior treatment at higher temperature, sigma developed more slowly, and was still increasing in amount at 7,500 hours. The results suggested that if sufficient time were allowed, all samples would contain about the same quantity of sigma, as would be expected on the attainment of equilibrium.

'4. Variation in cooling rate after prior treatment at 1700° or 1900°F. had little, if any, effect on precipitation of sigma at 1300°F. in 25Cr-20Ni steel, but after prior treatment at 2100° or 2300°F. the amount of sigma for any time at 1300°F. decreased directly with decrease of the cooling rate. This difference was especially marked during the early stages of sigmatizing.

'5. In 18Cr-8Ni-Nb steel, the rate of precipitation of sigma at 1300°F. was somewhat slower for prior heat-treatment at the two highest temperatures, 2100° and 2300°F., than for treatment at 1700° and 1900°F., but differences attributable to cooling rates were minor.'

The authors draw attention to the confirmation given by their results to the conclusion drawn by CLARK and FREEMAN that the 'unknown phase' found by them in similar steels was sigma (*Trans. Amer. Soc. Metals*, 1947, vol. 38, pp. 148-79; *Metal Progress*, 1948, vol. 35, pp. 366-7; *Nickel Bulletin*, 1947, vol. 20, Nos. 3-4, pp. 58-9; 1948, vol. 21, No. 5, p. 72).

The Chi Phase in Austenitic Nickel-Chromium Steels

K. W. ANDREWS and P. E. BROOKES: 'Chi Phase in Alloy Steels: Its Relationship to Sigma Phase.' *Metal Treatment and Drop Forging*, 1951, vol. 18, July, pp. 301-11.

The chi phase, with which this paper is mainly concerned, is apparently closely related to sigma. The authors therefore preface the account of their research on the chi phase by discussion of some theoretical and structural aspects of the two phases and the current state of knowledge on sigma. A succinct summary is made of observations which have been reported on the occurrence of sigma in various alloy systems, and of theories which have been proposed to explain it.

This review is followed by a detailed account of observations of the formation and effects of the chi phase in two types of materials: (1) heat-treated weld deposits, and (2) commercially cast steels supplied as rolled bar, or laboratory-cast ingots forged and rolled down to ½ in. diameter. The compositions covered by the steels were in the ranges nickel 7·6-15·4, chromium 15·12-23·04, molybdenum 0·87-5·04, per cent. Full particulars of composition of the individual specimens examined are tabulated.

The method used for detection of the brittle constituent and the carbides consisted of X-ray examination, by the powder method, of residues separated from the matrix by electrolysis. Most of the steels were also examined microscopically. The results are reported in detail, including tables showing the interplanar spacings of chi, sigma and carbide phases, and the structural conditions of the specimens after various forms of heat-treatment.

The results obtained lead to the conclusion that the occurrence of the chi phase is contingent on the presence of some molybdenum: it has not been found in any molybdenum-free steels.

Chi phase gives an X-ray powder pattern which is closely similar to that obtained with α-manganese, and the lattice parameter is generally in the region of 8·860 kX. Attempts to identify the phase microscopically have up to the present failed to differentiate it from sigma. It is not yet clear whether chi is a simple high- or low-temperature modification of sigma, but it is without doubt closely related to it, and occurs as an alternative to sigma in a manner which suggests analogy with transformations characteristic of cobalt.

The occurrence of a constituent such as chi, with a structure resembling that of α-manganese, is of interest in view of the relative positions of elements which form sigma phases, and of manganese itself, in the Periodic Table. It is considered that the discovery of chi has made some contribution to progress in explaining the occurrence and formation of sigma.

From the practical point of view, the two phases may

be considered to be very similar and to have similar properties. Their occurrence can be approximately related to the iron-nickel-chromium equilibrium diagram with the aid of factors equivalent to replacing chromium by

$$Cr+4(Mo+Nb)+3\,Si-12C.$$

The authors put forward a diagram which summarizes, qualitatively, existing information on elements favouring formation of sigma phase, and those promoting formation of austenite, ferrite and carbide. It is hoped that at a later date it will be possible to give the diagram a more accurate quantitative significance.

Thermal Conductivity of Nickel-containing Materials

See abstract on p. 200.

Nickel-containing Materials for Valves in Aero, Automobile and Diesel Engines

A. BALLERET: 'Valves for Aero, Automobile and Diesel Engines. Steels, Special Materials and Processes for Improving Behaviour at High Temperature and Resistance to Wear and Corrosion.' *Métaux*, 1951, vol. 26, June, pp. 256-68.

The paper opens with a review of the properties ideally required in valve materials, and a diagram showing the temperature conditions obtaining in service in inlet and exhaust valves. The opinion is expressed that no material yet available satisfactorily meets the requirements given for exhaust-valve alloys.

An account is then given of the various types of material and treatment which have been developed to withstand the conditions of temperature, stress, and corrosion to which the valves are subject, and to ensure the requisite physical properties. A table gives details of some exhaust-valve steels currently used in various countries.

Welded Joints between Dissimilar Materials in Steam Piping

R. U. BLASER, F. EBERLE and J. T. TUCKER: 'Welds between Dissimilar Alloys in Full-Size Steam Piping.' *Proc. Amer. Soc. Testing Materials*, 1950, vol. 50, pp. 789-808; disc. (jointly with paper by CARPENTER *et al.*, see next abstract), pp. 858-60.

The general trend in modern steam plants, towards increased pressures and higher temperatures, has led to the use of various austenitic nickel-chromium steels and alloys which differ markedly from the lower-strength ferritic materials in physical properties such as thermal conductivity, coefficient of expansion, modulus of elasticity, etc. The joining of the dissimilar austenitic and ferritic alloys presents design and fabrication problems, many of which are important factors in production of welded joints. The difference in the high-temperature load-carrying ability of the two types of material calls for special consideration, and the variation in physical characteristics may become of major importance if service conditions involve a large number of shutdowns or cycles of temperature and pressure. Microstructural changes during prolonged exposure to high temperatures may also have a deleterious influence on the properties of the welded joints.

In order to explore the effects of some of the factors which may thus affect the safety of ferritic-austenitic weld joints in steam piping, the authors devised a full-size proof test, involving maintenance of a specimen of composite piping at 1100°F. (593°C.) and 1500 p.s.i. internal pressure, with periodic shutdowns. Test equipment and specimen are described and illustrated: the set-up was designed to be representative of steam piping used in many installations.

The three materials employed were 18-8 chromium-nickel steel stabilized with niobium, a chromium-molybdenum steel ($2\frac{1}{4}$/1%), and a cast 16-13 chromium-nickel steel containing 2 per cent. molybdenum and stabilized with niobium. The last-named material was included on account of its frequent use in large steam valves. Electrodes used in making the test welds were of the 19-9-Nb type. The specimen consisted of a $10\frac{3}{4}$-in. diameter section of the chromium-molybdenum steel piping, welded to suitably designed and dimensioned end pieces of 18-8-Nb wrought and 16-13-Mo-Nb cast steels.

Analysis of the observations made (recorded in considerable detail, and with many photomicrographic illustrations), is not yet complete, but from a preliminary consideration it is concluded that the following stress conditions existed:—

(1) Residual stresses resulting from the welding operation.

(2) Operational stresses (circumferential and longitudinal), due to internal pressure, these stresses varying with pressure changes.

(3) Stresses resulting from differential expansion of the ferritic and austenitic materials. Such stresses vary in magnitude with changes in temperature and are at a maximum immediately after a major alteration in temperature.

(4) Stresses resulting from differences in the thermal conductivities of the two types of material. These stresses exist only during the heating and cooling cycles, and disappear at stable operating temperatures and in atmospheric conditions.

It is believed that the combined stresses may span a range larger than the yield-point stress at room temperature plus the limiting creep stress at operating temperature. Plastic deformation can therefore occur both at the room-temperature and the service-temperature ends of the cycle. The destructive action is aggravated by the fact that the two types of plastic deformation take place in opposite directions, and occur in the weakest part of the joint, i.e., in the narrow carbon-depleted zone next to the weld junction. Stress concentration at the weld metal/pipe metal interface promotes formation and inward propagation of an oxide notch in the less-oxidation-resistant chromium-molybdenum steel piping, and facilitates intergranular oxygen penetration, grain-boundary oxidation, and subsequent cracking. Tests are being made to evaluate the relative potency of the respective factors. Radiographic examination of the welds showed cracks in the chromium-molybdenum steel piping, at the edge

of the weld joint, after 4631 hours at 1100°F. (593°C.), a period involving 47 week-end shutdowns to atmospheric temperature.

See also—

O. R. CARPENTER, N. C. JESSEN, J. L. OBERG and R. D. WYLLIE: 'Some Considerations in the Jointing of Dissimilar Metals for High-Temperature High-Pressure Service,' *ibid.*, pp. 809-57; disc. (jointly with paper by BLASER *et al.*, see preceding abstract), pp. 857-60.

This paper summarizes some results obtained in a study, by Babcock and Wilcox, of conditions involved in, and effects resulting from, service in boiler units of a type permitting use of ferritic materials for a large part of the superheater section, but requiring austenitic materials at the outlet side. The work on which it is based comprised examination of dissimilar metal welds at the junction of austenitic to ferritic tubing, at metal temperatures to be expected in units operating in the gas-temperature range of 1900° to 2500°F. (1035° to 1370°C.).

The conditions experimentally imposed were considerably more severe than those normally encountered in service. The object of the investigation was not actual prediction of service-life expectancy of a weld between an austenitic and a ferritic material operating at high temperatures and pressures, but was rather designed to compare the high-temperature strength of austenitic and of ferritic tubing, with that of similar samples containing a butt weld joining of the two types of tubing. Such comparison was made, in a fatigue machine capable of testing full sections of superheater tubing when operating with internal pressure and at operating temperatures, by cyclic-quench equipment and by means of stress-rupture testing. The results of the tests not only demonstrated the effects of differential stresses, but also showed additional factors which are significant as affecting the life of joints forming transitions between dissimilar metals.

Apart from expansion stresses, these factors are basically metallurgical in nature, such as carbon-depletion in the heat-affected zone, oxide notches occurring in the ferritic material (and often in the carbon-depleted ferrite region), micro-fissuring of welds, and accelerated creep at the line of fusion.

Practical consideration is given by the authors to methods which may be adopted to increase the life expectancy of dissimilar-metal welds, and in this connexion an attempt was made to control carbon migration by stabilizing the carbide of the ferritic material by additions of various carbide-forming elements. The results indicated that both rate and degree of carbon migration from the ferrite to the austenite may be substantially reduced by additions of niobium, titanium, vanadium, nickel, or manganese (listed in decreasing order of effectiveness). Silicon appeared to be ineffective. Following the extensive series of tests reported, practical recommendations are made on procedure designed to give improved life expectancy in dissimilar-metal joints. These are briefly summarized below:—

'(1) The weld metal used may be either austenitic or ferritic, but each should demand an exacting control of the electrode itself and of the technique employed. This control should include careful shop tests of the electrodes, to ensure absence of fissuring. Careful procedures and welding details must be established. Welding techniques in production should be controlled to assure removal of crater cracking or other mechanical defects. The cover beads should be removed flush to the surface and all other stress raisers, such as notches and undercuts, carefully removed when they are near the fusion line.

'(2) No post-welding heat treatment need be given to welds joining ferritic to austenitic materials when the ferritic material does not show as-welded hardnesses over 350 Brinell, and when service temperatures exceed 950°F. (510°C.). This will reduce carbon depletion on the ferritic side and will lessen the rate of sigma formation in the austenitic weld metal.

'(3) The choice of welding composition seems to be a 19-9-Nb electrode for most applications.

'(4) The safe operating temperature limits to be expected of a dissimilar-metal weld appear to be a function of the operating temperature.

'(5) Where temperature and stress conditions are such as to indicate possible failure during the normal life of the assembly, it is recommended that all cyclic temperatures be prevented at dissimilar joints. This may be accomplished by separate heating applied to the outside of the joint: this procedure refers particularly to piping. On small tubing, such as in superheaters, the work reported would indicate that this precaution is not necessary under normal operating conditions.'

Brazing and Welding of High-Temperature Alloys

F. H. STEVENSON: 'Tips on Welding High-Temperature Materials.' *Iron Age*, 1951, vol. 168, July 19, pp. 109-11.

The article is based on the experience of the Aerojet Engineering Corporation, Azusa, California, where military rockets are produced in large numbers. Practical notes are given on (1) induction-brazing procedure, which is much used for making precision parts, (2) use of direct current in preference to alternating current in welding of the high-temperature materials, (3) welding of titanium, and (4) the inert-gas-shielded arc welding of stainless nickel-chromium steels. The article includes illustrations of welds in stainless steels made by the methods recommended.

Conservation of Nickel in High-Temperature Alloys

'Leaner Nickel Alloy.' *Iron Age*, 1951, vol. 168, July 19, p. 119.

To aid conservation of nickel, the International Nickel Company has developed a new alloy for use in high-temperature applications, particularly in those in which corrosive conditions are also involved. The alloy, designated 'Incoloy', contains about 35 per cent. nickel, 20 per cent. chromium, balance iron. It is available (in U.S.A.) in the form of sheet, strip, rod,

wire and tubing, and is expected to prove suitable for various applications in which alloys of higher nickel content, e.g., Inconel, were formerly used.

Conservation of Nickel: U.S. Orders

See abstract on p. 188.

Corrosion of Materials at Elevated Temperatures: A.S.T.M. Symposium

AMER. SOC. TESTING MATERIALS: 'Symposium on Corrosion of Materials at Elevated Temperatures.' *A.S.T.M. Special Tech. Publn.* 108, published 1951: 121 pp.

Contains papers and discussion presented at the Annual Meetings of the Society in June, 1950.

Abstracts of some of these papers, available earlier in preprint form, have already appeared in *The Nickel Bulletin*. In such cases the *Bulletin* reference is given in brackets after the title of the paper. Papers now published for the first time are abstracted below.

C. T. EVANS: 'Introduction,' p. 1.

Brief note on considerations which dictated the organization of the symposium, and on the evidence provided, by the papers presented, of the importance of corrosive attack as a factor affecting the serviceability of materials at high temperatures.

C. T. EVANS: 'Coal-Ash Corrosion of Metals at Elevated Temperatures,' pp. 3-8; disc., pp. 9-10. (*Nickel Bulletin*, 1950, vol. 23, Nos. 8-9, p. 166).

G. B. WILKES: 'Stress-Corrosion Tests on Turbo-Supercharger Materials in the Products of Combustion of Leaded Gasoline,' pp. 11-23; disc., pp. 24-5 (*Nickel Bulletin*, 1950, vol. 23, Nos 8-9, p. 166).

M. R. PICKUS and E. R. PARKER: 'Creep as a Surface-Dependent Phenomenon,' pp. 26-33.

The paper is concerned especially with the influence of surface condition of metallic materials on creep-resistance during the secondary stage, which is generally considered to be associated with atomic re-arrangements due primarily to thermal agitation, the external stress having mainly a directing influence.

The relevant literature, which is somewhat sparse, is considered at some length: most of the work done to date has been on single-crystal wires of tin and cadmium. In the light of the existing data, an attempt was made to formulate a programme which would start with the examination of single crystals of a pure metal from the hexagonal group (since in this case only one slip plane would be involved), continue with study of the same metal in polycrystalline form, and ultimately be extended to a high-temperature material, thus making a gradual approach to investigation of engineering high-temperature alloys. For the first part of the work zinc was chosen: for the second part nickel. This paper summarizes the results on zinc, and describes, in greater detail, results on nickel.

For the single-crystal *zinc* specimens a marked increase in resistance to creep was found to result from deposition of a thin layer of copper on the surface, but no such effect was observed with polycrystalline zinc. No difference was found in the temperature-dependence of creep rate between unplated single-crystal and polycrystalline zinc.

Behaviour of *nickel* (commercial grade) wire was examined, in atmospheres of hydrogen, helium and air. Creep rate in the second stage was determined, under a tensile stress of 2850 lb. at temperatures of 700°, 725° and 750°C. In a later series of tests an alloy of tungsten and nickel was electrodeposited on the surface of the nickel (to create a condition parallel to that existing on the copper-filmed zinc), and creep tests were made, in hydrogen. The presence of tungsten in the surface did not in any way affect creep-resistance.

Tests at 750°C., on nickel under a stress of 3650 p.s.i., in hydrogen, helium, and air, showed a creep rate in hydrogen more than double that occurring in air, and further tests confirmed the strengthening influence of the oxide layer formed on the air-tested specimens. It is suggested that if the presence of a thin layer of nickel oxide produces such a substantial increase in creep-resistance, the effect might be even more potent in the case of the oxides of other metals, such as aluminium or chromium. This possibility is to be explored in later stages of the same research, which is being carried out under the auspices of the U.S. Office of Naval Research.

O. C. SHEPARD and W. SCHALLIOL: 'The Effect of Environment on the Stress-Rupture Properties of Metals at Elevated Temperatures,' pp. 34-8; disc., pp. 39-41 (*Nickel Bulletin*, 1950, vol. 23, Nos. 8-9, p. 166).

A. M. TALBOT and E. N. SKINNER: 'Preliminary Studies of the Effect of Oxidizing Sulfurous Atmospheres on the Rupture Strengths of Inconel 'X' and Inconel,' pp. 42-8; disc., p. 49 (*Nickel Bulletin*, 1950, vol. 23, Nos. 8-9, p. 164).

C. A. ZAPFFE and F. K. LANDGRAF: 'Hydrogenizing Effect of Steam on Ferrous Alloys at Elevated Temperatures,' pp. 50-7; disc., p. 58.

The authors report experiments on several grades of hardenable stainless steels (400 series), heat-treated in atmospheres of (1) steam, or (2) carefully dried helium. The deterioration in ductility of specimens of the first group demonstrates the severe damage resulting from hydrogen derived from the high-temperature metal-steam reaction. The damage is measured in terms of bendability of $\frac{1}{4}$-in. round bar stock, using a specially developed bend test. It is shown that the action of steam is very rapid: exposure for one minute, at the close of treatment in dry helium, was found to cause virtually as much damage as a complete treatment under steam conditions. Recovery treatments were also studied. The observations made confirm the theory of the 'hydrogen potential' advanced by ZAPFFE some years ago (*Trans. Amer. Soc. Metals*, 1948, vol. 40, pp. 315-52).

C. T. EVANS: 'Oil Ash Corrosion of Materials at Elevated Temperatures.' pp. 59-105; disc., pp. 106-13.

The paper is introduced by a comprehensive review of the literature, supported by a *bibliography* of 38 references. Chemistry of, and constituents in, oil ash, and the nature of the attack caused by oil ash on metallic materials, are covered. It is noted that some of the numerous complex compounds which can be formed from vanadium are even more corrosive than the pentoxide: some of the vanadates are particularly suspect. The nature of these compounds is discussed.

Following this review, a highly detailed account is given of stress- and stress-free corrosion tests, made on a wide range of materials, in contact with various types of oil ash and with synthetic mixtures of vanadium-pentoxide and sodium-sulphate.

The microstructural condition of the specimens tested and analysis of corrosion products formed on the respective materials are also reported, and some account is given of tests in which attempts were made to lessen corrosive attack of the oil ash by addition of inhibitors to the oil.

Some of the conclusions drawn from the extensive series of tests reported are given below:—

The use of heavy (residual) fuel oil is believed to be a necessity in some areas, if the gas turbine is to compete successfully with other forms of power, but all service experience and laboratory tests confirm the corrosive nature of crude oils high in vanadium compounds.

Stress-corrosion tests on S-588 and 19-9 DL alloys, at 1350°F. (734°C.), run for periods up to 600 hours, in contact with oil ash containing about 6 per cent. vanadium, 5 per cent. sodium, 10 per cent. sulphur, gave the following results:—

The S-588 alloy was definitely corroded, particularly above the contact line, after exposure for 431½ hours. A thin ceramic coating was tried on this alloy, but the adhesion was not good. The corrosion attack observed was general, rather than intergranular, and this was also the case in later tests made in a more corrosive ash under stress-free conditions at 1350°F. (734°C.), on carbon steel and chromium-nickel austenitic steels. Under the latter conditions Inconel showed signs of intergranular attack. The 19-9 DL was not seriously corroded by this particular ash.

Tests without stress, run for one month at 1000°, 1350° and 1500°F. (538°, 734° and 815°C.), on a range of materials, using ash containing about 3 per cent. vanadium, 1 per cent. sodium and 8 per cent. sulphur, showed that this ash was not corrosive to any of the materials except iron-free aluminium bronze. The ash was not fused at any of the three test temperatures.

It was observed that heavy-oil ashes of the compositions given below showed evidence of low-melting constituents at 1000°F. (538°C.) and were essentially fluid at 1350°F. (734°C.) and 1500°F. (815°C.) An attempt to compare the corrosive qualities of these three ashes at 1500°F. (815°C.) resulted in complete failure of the heat-resisting-steel rack and most of the specimens.

	V %	Na %	S %
Ash from source A ..	44·5	2·0	3·0
„ „ „ B ..	35·0	1·0	0·15
„ „ „ C ..	18·0	15·5	7·5

Tests at 1000°, 1200° and 1350°F. (538°, 648° and 734°C.), on nine representative heat-resisting high-alloy materials, indicated that ashes A and B were much more corrosive than type C; even at the lowest temperature of test some reaction was noted, and the attack became more intense at the higher temperatures.

'Screening' tests (168 hours at 1350°F.: 734°C.) made in contact with the highly corrosive ash (A) led to the following observations:—

(1) Low-nickel or nickel-free iron-base materials were much more resistant to attack than high-nickel or cobalt-base materials. As a class, the 'superalloys' were the most readily attacked. Ordinary 18-8 steel was less heavily corroded than more-highly-alloyed austenitic types.

(2) Silicon impregnation by the 'Ihrigizing' process was found to be the most successful method of protecting carbon steel; 'Chromizing' was also effective. 'Siliconizing' (producing a chromium-aluminium case) did not prove so effective.

(3) Titanium carbide and mixtures of titanium carbide with cobalt, niobium and tantalum were heavily attacked, as were aluminium bronzes. Ceramic materials showed widely varying behaviour, and are believed to be highly sensitive to minor variations in purity and method of manufacture.

(4) No single class of materials can be considered completely immune from attack by this corrosive ash at 1350°F. (734°C.).

(5) Most of the materials which gave satisfactory resistance in the 168-hour test at 1350°F. (734°C.) in this ash showed heavy corrosion when the period of test was extended to 504 hours. 'Ihrigized' carbon steel was an exception. Increase in temperature to 1500°F. (815°C.) had an even more disastrous effect.

(6) In synthetic-ash tests (168 hours at 1350°F.: 734°C.), 18-8 straight chromium-nickel steel was not corroded when there was 2 per cent. or less vanadium pentoxide in the mixture, but attack on this steel in 100 per cent. vanadium pentoxide was more severe than in the highly corrosive natural ashes A and B. Attack was approximately constant with 10-80 per cent. vanadium pentoxide in sodium sulphate.

(7) Spectrographic analysis of the corrosion products indicates that both spinel-type oxides and vanadates may be formed on heat-resisting alloys corroded by ashes of types A and B, and by vanadium pentoxide.

(8) Physical contact with solid or molten ash is not a requirement for corrosion by heavy-oil ash: the vapours will cause heavy attack.

In view of the fact that certain components of gas turbines may have to stand at room temperature for extended periods with moist accumulations of heavy-oil ash, roof-exposure tests were made of materials in contact with ash. Materials showing adequate rust-resistance without ash were not severely attacked by moist ash.

It is concluded that no class of materials or protective coatings can be considered completely immune to attack by hot oil ash, over the temperature range of interest to gas-turbine builders (500°-1800°F.: 260°-980°C.). It is considered unlikely that a straightforward metallurgical solution can be found for all combinations of ash, temperature, and time involved: the materials showing the best resistance to oil-ash corrosion have, in general, the poorest high-temperature load-carrying ability.

The most hopeful line of attack is probably development of an economic oil treatment or oil-additive, which will render the combustion products inert, without unduly adding to erosion or fouling problems. In tests with 19-9 DL, lime (CaO) proved effective (CaO:ash, 1:1 or 3:1) and a mixture of 4·5 parts ash, 4·5 parts lime and 1 part calcium monophosphate was equally effective. The nature of the inhibitory action is discussed. Other additives which appear promising include sodium sulphonate and calcium sulphonate, which are already used in lubricating oils for other purposes. These compounds are soluble in heavy oil, whereas lime is not. An alternative method of inhibiting corrosion would be to add carbon tetrachloride, which might volatilize the active constituents of the ash. The corrosive character of the volatile constituents would, however, require consideration. A third possibility is dilution of the ash to a level of non-corrosive activity, but tests with Fe_2O_3, and Al_2O_3 and coal ash were not effective in the amounts tried in these tests.

Extensive discussion on the paper, which ranged from the behaviour of the metallic and other materials tested to the chemical character of the corrosive media, gave ample evidence of the number of investigators currently studying the problems involved.

W. N. HARRISON: 'The Growing Rôle of Protective Coatings for Metals in High-Temperature Service,' pp. 114-20; disc., p. 121.

Figures quoted in the introduction to the paper indicate the extent to which protective coatings are already being used, for example, on heat exchangers for large aircraft. The author reports results of tests made at the Bureau of Standards, under the auspices of the National Advisory Committee for Aeronautics. Pack-carburizing treatment on Type 321 stainless-steel sheet, (1) uncoated, and (2) ceramic-coated, showed carbon penetration to a depth of 0·008 in. in the uncoated specimen (with carbide precipitation in the grain boundaries), but no evidence of carbon infiltration in the coated specimen. Another series of tests, in lead-bromide vapour, was made at 1350°, 1500° and 1650°F. (734°, 815° and 898°C.), on Type 347 stainless steel, 19-9 DL, Inconel, Vitallium, and S-816, (1) coated with ceramic, and (2) uncoated. Photographs showing the condition of typical specimens after test, together with data reported in the text, indicate a higher degree of corrosion-resistance in the coated than in the bare specimens. The author emphasizes, however, that ceramic coatings, although occupying a valuable place as corrosion preventives, are by no means a cure-all, and that the physical properties of the materials on which such coatings are used, and the conditions of service, require careful consideration in selecting ceramic coatings for particular applications.

Oxidation of Nickel and of Cobalt

R. L. TICHENOR: 'Role of Oxide Composition in Oxidation of Nickel and Cobalt.' *Jnl. Chemical Physics*, 1951, vol. 19, June, pp. 796-7.

The author discusses theories which may be advanced to explain the observation that rate of oxidation of cobalt at 500°-800°C. in oxygen is many times greater than that of nickel.

Ceramic Moulds for Casting of Stainless Steel

H. CZYZEWSKI, R. L. COOK, P. FREDERICK and J. P. JERO: 'Cast Stainless Steel in Ceramic Molds.' *Amer. Foundryman*, 1951, vol. 20, July, pp. 38-9.

The authors report an investigation of moulds in five types of ceramic: the materials used were of the following compositions:—

(1) *Fireclay grog*: 50 per cent. calcined fireclay+a blend of high-grade fireclays.
(2) *Steatite*: a high proportion of talc+15 per cent. clay.
(3) *Cordierite*: a special blend of talc, alumina and clay, characterized by specially low expansion.
(4) *High alumina*: containing 75 per cent. pulverized tabular alumina, balance ball clays.
(5) *Zircon porcelain*: a high proportion of ground zircon, +clay and complex alkaline-earth zirconium silicates.

Each material contained 2½ per cent. of gum-arabic binder, and the amount of water varied from 3¾ to 7½ per cent.

The bodies were dry-pressed at 80 tons pressure; the press cavity, which limited the size of the moulds, was 9½ by 4¾ in.: pressure 3545 p.s.i. After pressing, the moulds were dried overnight at 300°F. (150°C.), in a recirculating-air drier, and were then fired for 16 hours.

Moulds of all the above types successfully withstood the thermal shock involved in casting the standard test-bar castings of 18-8 chromium-nickel steel. Fine details, such as the small screw threads, could not be produced more than once in the moulds, but the detail was excellent in the first pour. (Moulds could be used a second time if spring clamps rather than rigid clamps were employed and the detail of a casting was not too fine.) Effect of pre-heating the mould (at 300°, 600° and 1000°F.: 150°, 316°, or 538°C.) was determined, using mixture No. 1 above. The good surface appearance was but little affected, but accuracy of reproduction of fine detail was improved by pre-heating at the highest of these temperatures.

The mechanical properties of the castings were of a satisfactory order, except in the case of those cast in moulds pre-heated to 1000°F. All castings showed a dendritic structure; the grain-size of those cast in the 1000°F. pre-heated moulds was approximately six times that of the other specimens.

It is concluded that mixture 4 is the best all-round ceramic mould material for the purpose, and it also offers the possibility of obtaining zero shrinkage, if firing temperature is closely controlled.

Stainless Iron and Steel: Reference Data

J. H. G. MONYPENNY: 'Stainless Iron and Steel. Vol. I. Stainless Steels in Industry.' 3rd edn., revised. Published by Chapman and Hall, Ltd., London, 1951; 524 pp. Price 45/-.

The very large amount of information which has become available during recent years, on stainless irons and steels, led to the decision that the revision of the author's classic work on this subject should be divided into two volumes, bearing, respectively, the sub-titles 'Stainless Steel in Industry' and 'Microstructure and Constitution'.

Volume I of the revised edition deals, therefore, with the essentially industrial aspects of these materials. The varieties of stainless steel in commercial use are described in the first chapter, which includes much information on compositions, characteristics and properties which are of practical interest to engineers and workers in metals. Later chapters contain equally practical data and recommendations relating to methods of fabrication, and the behaviour of the various steels and irons under conditions of stress, corrosive attack and temperature involved in service of widely diverse nature. The final chapter is concerned with the selection of stainless steels for specific industrial uses, dealing with types suitable for domestic, hospital, decorative and architectural uses; power-plant, aeronautical, automobile, railway and general-engineering purposes; chemical-engineering plant and equipment; heat-resisting applications.

The book is amply illustrated, and much information is presented in a ready-reference form. An appendix contains tabular data on physical properties typical of the various grades of steel and iron coming within the scope of the book: information is given on density, coefficient of expansion, specific heat, thermal conductivity, electrical resistance, and magnetic properties.

The literature of the subject is well represented, and a detailed subject and author index is provided.

Volume II is to be published later.

Mechanical Properties of Nickel-Alloy Steels

See abstract on p. 199.

Nickel and Nickel-Alloy Pipe and Tubing

See abstract on p. 194.

Structure of Austenitic Nickel-Chromium Steels in Relation to Intergranular Corrosion

L. COLOMBIER and J. HOCHMANN: "Intergranular Corrosion of Stainless Austenites.' *Comptes Rendus*, 1951, vol. 232, July 9, pp. 176-8.

The author demonstrates the dehomogenization of stainless steels occurring on heating at high temperatures, as contributory to the occurrence of intergranular corrosion after heating within the sensitizing range, e.g., during welding.

Photomicrographs of an 18-8 steel containing tungsten show that heating at 1150°C. (followed by water quenching) results in formation of a frame of a white constituent surrounding the grains, whereas in the interior of the grains numerous carbides remain undissolved. This is explained as due to concentration of carbon in the actual grain boundaries (at the expense of the neighbouring regions) resulting from surface tensile stress occurring on heating, as suggested by the author in a former communication.

This observation, and the theory put forward to explain the occurrence of the carbon migration, is considered to assist in explanation of the phenomenon of intergranular corrosion. The theory of chromium impoverishment is admitted to have been proved beyond doubt in cases in which prolonged sensitization is in question, but it is considered to be inadequate to account for sensitization on short exposure. If, however, it is realized that the condition of the steel prior to exposure in the sensitizing range already shows some degree of inhomogeneity, and that carbon is already present in the grain boundaries, it is reasonable to assume that it may precipitate as carbide after only very short exposure in the danger range, without any presumption of necessity for a diffusion stage.

'Malcomizing' (Nitriding) of Stainless Steel

S. LOW: 'Nitriding Stainless Steels for Better Wear Resistance.' *Steel*, 1951, vol. 129, Aug. 6, pp. 82, 84, 86.

An account is given of the Malcomizing process, in which treatment with nascent hydrogen is employed to reduce the thin layer of chromium oxide on stainless steels, prior to a conventional nitriding treatment. Furnace installations used for operation of the process are illustrated.

Much emphasis is placed on the importance of correct prior heat-treatment, for steels which are to be surface-hardened by this process. As in the case of the lower-alloy steels, pre-nitriding structure should be sorbitic, and all residual stresses should be removed. Surfaces are prepared for nitriding by fine sand-blasting. Total length of the Malcomizing cycle is about 40 hours, and after treatment the parts are finished by light grinding, lapping, honing or polishing.

Typical curves showing case-hardness/depth relationships in the treated steels indicate that maximum hardness is reached at about 0·002-in. below the surface.

With regard to the corrosion-resisting qualities of Malcomized stainless steels, it is noted that the nitriding treatment somewhat lowers resistance (particularly in mineral acids, their salts and strongly oxidizing acids), but that passivation, in mild oxidizing solutions such as sodium dichromate, appreciably enhances resistance to many media.

Although the principal advantage conferred on stainless steels by nitriding is improved resistance to wear, such treatment also appreciably improves fatigue strength: the effect of Malcomizing, on the fatigue strength of notched high-chromium steel, is demonstrated in this article.

It is also claimed that the stability of Malcomized

steels at elevated temperatures is good. Laboratory tests quoted indicate that although the nitriding treatment is performed at 1,000°F. (538°C.), the hardening reaction is not readily reversible. Exposure of nitrided nickel-chromium steels for 100,000 hours (nearly 12 years) at 1025°F. (552°C.) has been found to lower the hardness of the case by only about 50 per cent., and heating at lower temperatures has appreciably less effect. Treated stainless steels show good wear-resistance at temperatures up to 1200°F. (650°C.). With regard to the design of components suitable for treatment, two rules must be observed: (1) sharp corners should be avoided, and (2) unit bearing pressures should be kept below the yield point of the core material: higher pressures are liable to result in 'brinelling' and ultimate fracture of the case. If specially high core hardnesses are essential, the precipitation-hardening grades of stainless should be used: these are fully susceptible to treatment by the Malcomizing process.

Successful applications of nitrided stainless-steel parts range from high-temperature, high-pressure valve trim to dental-drill handpieces. Some typical components are illustrated.

Surface Hardening of Steel

See abstract on p. 202.

Sub-Zero Properties of Metals and Alloys

See abstract on p. 199.

Behaviour of Nickel-Chromium Austenitic Steel in the Acidified Copper Sulphate Test

J. BLÉTON, J. BLANOT and P. BASTIEN: 'Statistical Investigation of the Resistance of 18-8 Chromium-Nickel Steel to Corrosion by Acidified Copper Sulphate Solutions.' *Rev. de Métallurgie*, 1951, vol. 48, July, pp. 325-36.

Following observations of inconsistent behaviour in the acidified-copper-sulphate test, of nickel-chromium steels of nominally identical composition, a statistical investigation was made on 91 casts of the following average composition: carbon 0·025–0·080, chromium 18–20, nickel 9·5–11·5, manganese 0·4–0·6, silicon 0·25–0·55, sulphur and phosphorus less than 0·025 each, per cent.

The following treatments were given:

(1) Holding for 30 minutes at 1050°C., followed by air cooling;

(2) Sensitization treatment, comprising heating at 650°C. for 30 minutes (as specified by the British Air Ministry), or for six hours, followed by air cooling. After the above treatments the specimens were polished on 000 emery paper, degreased, and weighed, before exposure, for 72 hours, to a boiling solution containing sulphuric acid 10, copper sulphate 10, water 80, per cent.

On completion of this test, loss in weight, and loss of ringing tone were examined, and bend tests were made.

Statistical examination of the results, which are individually reported, indicates that behaviour under the intergranular-corrosion test is closely dependent on the carbon and chromium contents of the steels, whereas nickel appears to have but little influence. Statistical analysis of the results leads to the suggestion that a cast may be given an index value relating its carbon and chromium contents, and that by its use it is possible to trace probability diagrams which permit forecasting the satisfactory or unsatisfactory behaviour of the steel in relation to its carbon and chromium contents.

Resistance of Stainless Steels to Corrosion by Sour Crude Oils

C. P. LARRABEE and W. F. ROGERS: 'Stainless Steels for the Bottoms of Tanks containing Sour Crude Oil.' *Corrosion*, 1951, vol. 7, Aug., pp. 276-8.

Corrosion of the bottoms of steel storage tanks containing sour crude oil has been a problem in the oil industry for many years: the corrosion is caused by the sulphide-bearing salt water which separates from the crude oil. Attack on carbon steels is rapid, and although some degree of protection has been effected by certain types of coating, localized corrosion is apt to occur, through pinholing of the coatings or damage to them in erection or service. This paper reports investigations made in an endeavour to find a material more resistant to attack.

Specimen panels of Types 304, 316, 316 extra-low-carbon, 317, 410 and 430 steels were tested, as well as samples of welded 316-Nb, 316 extra-low-carbon, and 347. The welds were made with rods of compositions similar to those of the parent steels.

The specimens, fixed into an insulated frame, were placed in the aqueous phase of a gun barrel, which is a tank (in this case of 50-barrel capacity) into which the oil-and-water mixture produced by a pumping well is accumulated, and in which the major portion of the water is separated and discarded. This barrel is of wood: the specimens were therefore not in contact with any metallic parts during test. The mixture was at atmospheric temperature and the water used is believed to have been practically free from oxygen.

One frame of specimens was removed after six months, the other after one year. Visual and metallographic examination was made, supplemented by loss-of-weight determinations.

The ferritic stainless steels were found to have suffered very severe attack, worse than that on the carbon-steel control specimens, but the austenitic nickel-chromium steels of the 304, 316, 316 extra-low-carbon, 316-Nb and 317 types were unattacked. The 347 steel had suffered a pitting form of corrosion. No evidence of intergranular attack was found on any of the specimens, even in the heat-affected zones of the welded samples. A tarry coating which formed on the specimens during the one-year test appeared to give some degree of protection to the carbon steels, but did not benefit the ferritic steel samples: the reason for this difference is not yet clear.

Sea-Water Spray Testing of Metallic Materials

T. P. MAY and A. L. ALEXANDER: 'Spray Testing with Natural and Synthetic Sea Water. Part I. Corrosion Characteristics in the Testing of Metals."
Proc. Amer. Soc. Testing Materials, 1950, vol. 50, pp. 1131-41; disc. pp. 1142-3.

In connexion with corrosion experiments which were to be conducted in synthetic sea water, the U.S. Naval Research Laboratory some years ago made an examination of existing formulae for such solutions. The results indicated serious discrepancies. A literature survey was therefore conducted, to establish a a summary of existing knowledge on the composition of sea water from various parts of the world. This permitted development of a formula which would provide an exact duplicate of the organic components of natural ocean water, and during 1948-1950 many corrosion tests were carried out with this solution, in order to evaluate it as a corrosive medium.

This paper presents a correlated account of the nature of sea waters from various sources, and gives results of comparative tests made (1) in spray cabinets, using 3 and 20 per cent. sodium-chloride solutions, (2) in natural sea water, and (3) in the proposed solution, which shows ion concentrations closely similar to those of natural sea water:—

The following materials were exposed for test: ingot iron containing 0·4 per cent copper, steels containing 0·05 and 0·27 per cent. copper, rolled zinc, zinc plating electrodeposited on low-copper steel, nickel plating electrodeposited on low-copper steel, titanium. Specimens of the same materials were also exposed in a marine atmosphere and in sea water at Kure Beach, N.C.

The test results revealed little similarity of performance between specimens exposed in the natural environments and those tested in the spray cabinets using sodium-chloride solutions. One exception was the nickel-plated steel immersed in sea water, in which case all the spray tests caused a similar type of failure. In tests on ingot iron and plain steels the spray tests with natural and synthetic sea waters did not duplicate the types of corrosion usually observed in natural marine atmospheres. Zinc-plated steel and solid zinc sheet, however, corroded in a similar manner in spray cabinet conditions (using both natural and synthetic sea waters) and in atmospheric exposure, but the corrosion rates were not sufficiently high to warrant considering such cabinet tests as accelerated tests. The following comment is made on the behaviour of the nickel-plated specimens.

'Specimens Electroplated with 0·001-in. of Nickel on Steel

In sea water, all specimens developed rust stains in 24 hours, and 0·06-in. steel specimens perforated in 14 days at some of these pinholes. The spray cabinets produced a similar result. Failures at a few large pinholes became evident in 24 hours in all cabinets. All specimens failed in 7 days, and it is difficult to say which test condition was the most corrosive. A general observation would place the spray solutions in order of decreasing corrosivity as—

(1) 20 per cent. sodium chloride,
(2) 3 per cent. sodium chloride, and
(3) natural and synthetic sea water.

In the atmosphere, numerous small pinholes appeared, with light rust staining around them. In 165 days there was little difference between specimens located 80 and 800 ft. from the ocean.

'The great difference in attack on nickel-plated steel in the cabinets and in the atmosphere may be readily explained. In the cabinets and in sea water, where the surfaces are continuously wet, the first pinholes to appear in the coating expose steel which then serves as an anode, to protect cathodically the remaining intact nickel surface. Hence, only a few pinholes develop and these exhibit a severe attack. In the atmosphere, the specimens are not continuously wet by conducting solution and the coating does not receive cathodic protection from the early breaks in the coating. Therefore, a large number develop, in each of which the corrosion is slight in comparison to the specimens continuously wet with conducting solution.

'Because of this radical difference, it is questionable what can be said about the behaviour of nickel-plated steel in the atmosphere, on the basis of salt-spray tests. On the other hand, sea-water immersion and spray-cabinet tests produce the same type of failure, the latter being the less severe exposure.'

A second part of the paper reported spray tests on organic coatings, *ibid.*, pp. 1144-9; disc., p. 1150.

Marine Corrosion-Testing Station at Harbor Island, N.C.

'Harbor Island Station Increases Facilities of Kure Beach Project.' *Inco*, 1951, vol. 24, No. 4, pp. 4-9, 28-9.

The opening of the new Harbor Island testing station, by the International Nickel Company, has increased by more than 100 per cent. the facilities for studying the destructive action of sea water on metals, wood, paint, anti-fouling compounds, rope, plastics and other materials. The station consists essentially of a laboratory building which provides 5,280 square feet of indoor testing and study space, conference and office rooms, record files, and maintenance equipment, as well as racks and other equipment for sea-water exposure studies. Atmospheric testing is still being carried out at the original marine site, Kure Beach, where investigations were started in 1935.

This article gives a well illustrated account of the layout and work of the Harbor Island station, and of the nature of the investigations in progress at both locations. Among the advantages resulting from addition of the Harbor Island resources are a continuous supply of full-strength uncontaminated sea water; a relatively wide range of sea-water temperature; a long season of growth of marine organisms: protection against the physically destructive effects of storms and high waves; fluctuation in water level, of a degree permitting observation of waterline and intermittent-immersion effects; availability of improved test equipment and maintenance facilities.

Corrosion Resistance of Sprayed Nickel-Chromium Steel Coatings

O. VAN ROSSUM: 'Corrosion-Resistance of Sprayed Austenitic Materials.' *Metalloberfläche*, 1951, vol. 5, Aug., pp. A113-15.

In order to determine the cause of unsatisfactory corrosion-resisting qualities of sprayed coatings of nickel-chromium austenitic steel, comparative tests were made on wires of steels of the compositions shown below, and of sprayed coatings, 3 mm. thick, deposited from them.

Composition of Wires and Sprayed Layers

	C %	Cr %	Ni %	Mo %	Ti %	Ta %	Nb %
Wire	0·09	20·6	9·2	0·43	0	0·26	0·94
Sprayed Metal	—	18·8	9·4	0·25	0	0·24	0·76
Wire	0·06	19·9	8·4	2·05	0·20	0	0
Sprayed Metal	—	19·4	8·7	2·02	0·20	0	0

The physical characteristics of the materials were determined by hardness tests, and by microscopical examination, and corrosion tests were carried out in boiling 40 per cent. nitric acid, in 99·8 per cent. acetic acid, and under the conditions of the standard acidified copper-sulphate test for intergranular corrosion.

A marked difference was observed between the attack of the sprayed materials in the nitric acid and the copper-sulphate solutions, and that occurring in the acetic-acid solution. In the first two cases the oxide layer is pushed off the metal, exposing a large area of material to attack. In acetic acid the oxide layers are gradually dissolved away, and the speed of penetration of the acid into the metal is therefore contingent largely on rate of dissolution of the oxide, which gradually slows down.

The results indicate that, quite apart from the inherent porosity of sprayed layers, which tends to lower corrosion-resisting quality, a good degree of resistance cannot be anticipated in such coatings until means are devised for depositing the sprayed metal in a less heavily oxidized condition.

Materials for Pickling Equipment

E. A. TICE: 'Materials of Construction for Pickling Operations prior to Electroplating.' *Plating*, 1951, vol. 38, Aug., pp. 826-30.

The paper reviews corrosion-resisting materials suitable for construction of equipment used in the pickling operations which are so important a stage in the preparation of materials for electroplating. Since the choice of acids to be used for pickling depends primarily on the nature of the material being pickled, the discussion is classified in sections relating to the various types of base metal treated. Some of the main points are extracted in the following notes.

Iron and Steel

The most commonly used solutions are sulphuric and hydrochloric acids. Hydrofluoric acid may be used for removal of silica coatings on the surface of sand castings. Sodium acid sulphate solutions may be used in place of sulphuric acid, for pickling of steel parts.

Tanks for *sulphuric acid* or *sodium acid sulphate* solutions are usually made of lead or rubber-lined steel, acid-resisting brick, or unlined spruce or yellow pine. Monel tie rods are successfully used in wooden-tank construction. For barrels, baskets or hooks handling steel parts, Monel and acid-resisting bronze have proved suitable. An automatic pickling machine, in which Monel is extensively employed, is described and illustrated.

The choice of materials for handling *hydrochloric acid* is more limited. Tank linings of synthetic or natural rubber, or of plasticized polyvinyl-chloride resins are suitable, and carbon or graphite-brick linings can be used over a wide range of acid concentration and temperature. Monel may be used for tanks containing up to 10 per cent. acid at room temperature, but will corrode at somewhat high rates if the bath is aerated, or if the solution is used hot. In such conditions it is not recommended for tank service. Pickling baskets or barrels of Monel give reasonably long life if they are completely submerged when in use, but Monel is not satisfactory for partially immersed or aerated conditions. If highly aerated conditions are involved Hastelloy B is the preferred container material. Non-metallic materials of various types have been successfully employed in this form of service.

In pickling with *hydrofluoric acid*, for removal of sand, it should be noted that the reaction of silica with the acid causes formation of fluosilicic acid, and that if Monel is in a stressed (cold-worked) condition stress corrosion may occur. Annealed Monel has, however, been found satisfactory for the purpose.

Copper-base Alloys

Removal of oxides from copper-base alloys is usually accomplished in a *dilute solution of sulphuric acid* or a *mixture of sulphuric acid and sodium dichromate*. With use, the copper-sulphate content of the solution builds up, acting as a good inhibitor of corrosion of stainless steel. (As a precautionary measure, some copper sulphate is sometimes added to a new bath). The austenitic stainless steels can therefore be used for both tanks and pickling baskets:

the molybdenum-containing types are to be preferred under conditions involving extra high temperatures.

The suitability of Monel for service in equipment pickling copper-base materials depends upon whether oxidizing or reducing conditions prevail. In an unaerated sulphuric-acid bath, Monel shows fairly high resistance to corrosion, but if the solution is aerated, or if a dichromate is present, the oxidizing conditions greatly accelerate corrosion and Monel is not recommended for use. Results of corrosion tests on various metals and alloys, quoted in this review, illustrate the behaviour of the austenitic stainless steels and Monel under various conditions.

For bright dipping of copper-base materials, oxidizing salts, such as dichromates or nitrates, or nitric acid, are usually added to sulphuric acid; typical compositions of *bright-dip solutions* are given. In these solutions the behaviour of Monel, acid-resisting bronzes, and lead is unsatisfactory, but Inconel, the stainless steels, Worthite and Durimet usually exhibit excellent resistance to corrosion. Inconel is much used for the dipping baskets, the alloys containing nickel, chromium, iron and molybdenum for pumps and valves, and type 316 (molybdenum-containing) nickel-chromium steels for tanks.

Aluminium and its Alloys

A bright etch finish is produced on these materials by immersion in a *hot alkaline solution, e.g., a bath containing* 2-8 *oz./gal. of sodium hydroxide, sodium carbonate or trisodium phosphate*. Steel equipment satisfactorily withstands such solutions, and highly alloyed materials are not required. For smut removal a *hydrofluoric/nitric acid* bath is used, and for this vinyl-resin tank linings are most satisfactory. In pickling of the aluminium-base materials nitric-hydrofluoric acid mixtures of higher concentration are used and recent experience has indicated that an extra-low-carbon type 316 steel has a tolerable resistance to corrosion at temperatures up to 140°F. (60°C.). For tanks handling stronger solutions of the same type Koroseal appears to be a satisfactory lining material.

Magnesium

Three types of solution are used: (1) *chromic acid-calcium nitrate*, (2) *dilute sulphuric acid*, and (3) a *dilute nitric-sulphuric acid* bath. For type 1 lead-lined steel, stainless-steel or aluminium-alloy tanks may be used; for type 2 ceramic, or rubber- or lead-lined tanks are preferred, and for type 3 ceramic or stainless-steel tanks may be used.

Zinc-base Alloys

Because most of these castings are buffed in the course of preparation for plating, pickling, in the usual sense, is not a necessary pre-plating step. Prior to copper-plating, however, a *sulphuric-acid dip* is used, concentration 1-4 per cent. by volume. The tank materials generally employed for handling the higher concentrations of sulphuric acid are suitable for this service and Monel or stainless-steel baskets are suitable. For removal of the white zinc-corrosion product sometimes formed on storage a strong chromic-acid solution containing a small amount of sodium sulphate is used. Steel or stainless-steel tanks and baskets are reported to have proved satisfactory for this service.

Materials of Construction for Handling Sulphuric Acid

S. W. SHEPARD: 'Materials of Construction for Handling Sulphuric Acid.' Report of N.A.C.E. Technical Practices Committee TP.5A.
Corrosion, 1951, vol. 7, Aug., pp. 279-82.

Critical summary, based on survey of existing information made available to the Committee, from the literature and other sources.

The behaviour of sulphuric-acid solutions of various concentrations and at various temperatures, and the suitability of non-metallic and metallic materials for handling them, is considered under the headings of natural and synthetic elastomers, lead, silicate cements, furane-base materials, phenol-formaldehydes, moulded and laminated structures, polyfluorethylene resins, fibre, vinyl resins, aluminium, iron and steel, high-silicon cast irons, stainless steels, nickel and its alloys, Hastelloy and Chlorimet alloys, precious metals. The statements made are of a general, rather than a particularized, nature.

It is indicated that the Committee would be glad to receive details with regard to actual plant corrosion tests and experience, of which it is felt that a large amount must be held by many chemical-engineering and other organizations.

Resistance of Stainless Steel to Corrosion by Lithium

'Stainless on Copper Halts Lithium Attack.'
Iron Age, 1951, vol. 168, Aug. 16, p. 114.

In tests made at Oak Ridge National Laboratory, to enrich the stable isotopes of lithium by the electromagnetic process, it was desirable to use lithium metal as the charge material. Initial experiments had, however, indicated that the corrosive action of hot lithium, on the copper castings of the source unit, would preclude its use unless some method of protection could be found. Search of the literature indicated that cast iron had the necessary corrosion-resisting quality, but this material could not be used, due to the fact that it is magnetic. A successful solution of the problem was found by spraying the copper with non-magnetic nickel-chromium stainless steel, to a thickness of about 0·015 in. Castings sprayed with stainless steel have also been used with equally good results in processing of potassium.

Nickel-containing Materials in the Dairy Industry

M. JEAN-BLAIN: 'Corrosion-Resisting Materials in the Production of Pure Milk.' *Rev. du Nickel*, 1951, vol. 17, July-Aug.-Sept., pp. 53-62.

This article, by a member of the staff of the École Nationale Vétérinaire de Lyon, opens with a brief discussion of the problems involved in production of clean, pure milk, and subsequently reviews the properties and uses of metallic materials employed, for various purposes, in the dairy industry. The suitability of the respective types is considered in relation to the action of the metals on the milk, and *vice versa*, the mechanical strength of the metals, and their resistance to corrosion by the cleaning and detergent agents used in maintenance of dairy equipment. The value of the stainless steels is especially emphasized, and

their many uses are described and illustrated, as related to the successive stages of milk-handling and processing: the milking apparatus used on the farm; transport equipment; the pasteurizing plant, and bottling machines.

Nickel-containing Materials in Plant Producing Methallylamine

R. S. TRESEDER and R. F. MILLER: 'Corrosion in the Ammonolysis of Aliphatic Chlorides.' *Corrosion*, 1951, vol. 7, July, pp. 225-8.

In the course of development, by Shell Development Company, of a continuous process for the manufacture of allylamine or methallylamine, by ammonolysis of the corresponding chlorides with liquid ammonia, certain severe corrosion problems were encountered. One case involved the reactor, the other the amine-recovery system. During investigation of these cases it was found that relatively novel corrosion reactions were involved, about which but little information was available in the literature. Laboratory study was therefore initiated, using synthetic mixtures comparable to the plant streams involved, in order to identify the essential corrosive components and to determine the influence of variable factors which might influence their effect. This paper describes some of the observations made.

Conditions obtaining in the processes involved are described, with flow diagram of the methallylamine pilot plant, and a report is made of tests in which the behaviour of a number of materials was determined in two of the most severely corrosive streams encountered, one essentially an anhydrous solution of ammonium chloride in liquid ammonia, the other a mixture containing methallylamine and unreacted aliphatic chloride. The two systems were found to have similar corrosion characteristics. The materials exposed for test included carbon steel, various grades of austenitic nickel-chromium steel, Worthite, Durimet T, copper, 70-30 copper-nickel alloy, Monel, nickel, Inconel, and Hastelloys B and C. Results of the tests are tabulated.

The laboratory tests, together with experience in the pilot plant, led to the conclusion that, in the conditions prevailing in the methallylamine process, highly alloyed nickel-chromium steels, e.g., of the Worthite type, or nickel-molybdenum-chromium-base materials of the Hastelloy C type, are required for the reactor, and that molybdenum-containing stainless steels should be used for the ammonia stripper reboiler, in which the active corrosive is a mixture of amines and organic chlorides.

The authors call particular attention to the corrosive nature of solutions of ammonium chloride in liquid ammonia, and of mixtures of organic chlorides and amines or nitriles. In both cases the presence of water proved to be unimportant, but temperature was a strongly accelerating factor.

The Pressure-Welding Process: Its Application to Nickel-containing Materials

See abstract on p. 188.

Extra-Low-Carbon Steel Electrodes for Welding Austenitic Steels

R. K. LEE: 'Arc Welding Stainless Steel without Columbium.' *Welding Jnl.*, 1951, vol. 30, May, pp. 447-9.

The author discusses, in simple terms and with typical illustrations, the occurrence of the heat-affected zone in welded austenitic steels, its characteristics, the occurrence of intergranular corrosion, and the influence of such corrosion on the behaviour of welded parts in service.

Use of niobium as a stabilizer is now limited by the placing of this metal on the critical list of strategic materials.

The aim of this article is to demonstrate the possibility of producing entirely satisfactory arc welds in austenitic nickel-chromium steels by means of extra-low-carbon nickel-chromium steel electrodes. Typical welds made with such rods are illustrated, to indicate the freedom from susceptibility to intergranular corrosion obtainable by this means.

'Sigma' Welding of Nickel-Chromium Stainless Steel

H. T. HERBST: 'Sigma Welding of Non-Ferrous Metals and Alloy Steels.' *Welding Jnl.*, 1951, vol. 30, July, pp. 618-31.

'Heliarc welding', using a non-consumable tungsten electrode in an inert-gas atmosphere, has found increasing use during the past few years, and the principles of the process have recently been further applied in the 'sigma' process (shielded inert-gas metal-arc welding), in which a consumable electrode is used. Heat liberated by the arc causes melting of the filler rod into small droplets, which are transferred across the arc to the work.

This paper describes the essential principles and features of the sigma process, equipment used and technique, and its applications.

Among the uses of the process already developed are the joining of aluminium and aluminium alloys and copper and copper alloys, surfacing of aluminium-base materials, welding of carbon steel, and welding of nickel-chromium steel. Conditions of operation are described for use with the respective materials.

Welding of Copper-bearing Stainless Steels

H. THIELSCH: 'Welding Copper-bearing Stainless Steels.' *Welding Jnl.*, 1951, vol. 41, July, Suppl. pp. 341-7.

This review is one of the series being prepared under the auspices of the Literature Advisory Committee of the Welding Research Council. It is to be read in conjunction with 'Copper in Stainless Steels', a detailed discussion of the physical metallurgy of the copper-bearing stainless steels, published as Welding Research Council Bulletin No. 9, August, 1951. The Bulletin deals with phase relations, hot-working properties, corrosion-resistance, age-hardening characteristics and the influence of other alloying elements, and thus forms a background to the present review of the welding qualities of the copper-bearing steels.

The information on welding is presented in four sections, relating respectively to:—

(1) Martensitic or ferritic steels containing up to 30 per cent. chromium, 0-3 per cent. nickel, and up to 1 per cent. copper, as used for corrosion-resisting applications in marine service and in some types of food-handling equipment.

(2) Austenitic (and partially ferritic) steels containing up to 30 per cent. chromium, 3-10 per cent. nickel, and up to 4 per cent. copper. Such materials are used for applications in which a good degree of age-hardening, together with high corrosion-resistance is required.

(3) Austenitic stainless steels containing 12-30 per cent. chromium, and 10-20 per cent. nickel, with 2-4 per cent. copper, as used for high-temperature applications, e.g., in gas- and steam-turbines, superheaters, etc.

(4) High-nickel austenitic steels containing 15-30 per cent. chromium, 20-35 per cent. nickel, and 2-5 per cent. copper, used primarily in applications in which a high degree of corrosion-resistance is essential, for example in contact with solutions or slurries containing sulphuric, acetic and other reducing acids.

It is noted, as a general observation, that although copper is readily transferred from the electrode to the weld deposit, the element in some cases produces undesirable effects, due to its tendency to precipitate in the form of copper-rich alloy phases.

The martensitic and ferritic types of copper-bearing stainless steel are usually welded with standard copper-free 25-12 or 25-20 chromium-nickel steel electrodes. In most corrosion-resisting applications for which these steels are used the higher alloy content of the weld metal sufficiently compensates the advantages gained by the copper in the lower-alloy parent metal.

For the austenitic copper-bearing chromium-nickel steels it is usual to employ electrodes of compositions similar to those of the parent steels. In the absence of ferrite from the weld metal the deposits tend to be liable to cracking under restrained welding conditions, but this effect can normally be prevented by careful control of electrode composition (low-silicon), correct welding technique (use of low welding currents and short arcs, and cooling of the weld metal between the runs), and in some cases, by pre-heating the joint.

Since the carbon content of austenitic stainless steels is usually below 0·07 per cent., welding alone does not usually produce sufficient carbide precipitation to make the steels susceptible to intergranular corrosion in service, but in cases where the steels are to be exposed for long periods in intermediate temperature ranges which would give rise to carbide precipitation, addition of stabilizing elements such as niobium, tantalum or titanium to the steel, and niobium and/or tantalum to the electrode, is necessary.

The review is based on world literature and on unpublished information communicated to the author from many sources: a *bibliography* of 20 references is appended. Full details of technique of welding the respective types of steel, and the properties obtainable in the welded joints, are summarized in convenient reference form.

Cracking in Austenitic Weld Deposits

R. MONTANDON: 'Chemical Composition of Austenitic Electrodes and Crack Susceptibility of Weld Deposits.' *Brown Boveri Rev.*, 1951, vol. 37, July, pp. 255-64.

The author makes a short review of the relevant literature and gives results of tests made, in the Brown Boveri laboratories, using forty welding electrodes obtained from various sources (American, English, Swedish, German and Swiss). Welds made with these electrodes were examined, *exclusively from the point of view of cracking susceptibility*, in relation to composition. The parent material on which the welds were made was 15-mm. chromium-nickel-molybdenum steel plate (carbon 0·3, silicon 0·3, manganese 0·6, chromium 0·25, nickel 2·0, molybdenum 0·2, per cent.), bevelled to give a single V with a 60° included angle. These plate specimens were pre-heated to 300°C. and butt-welded with each brand of electrode, under conditions conforming to Standard 14,051 of the Verein Schweizerischer Maschinenindustrieller, a seal bead being finally deposited. The welded plates were subsequently stress-relieved by heating at 650°C. for one hour. Specimens used for tensile, bend and notched-bar impact tests conformed to V.S.M. Standard 14,051. A second welding test, conforming to V.S.M. standard 14,052, and similar to the Swinden-Reeve test, was made on a test specimen of welded boiler plate, which was neither pre-heated nor subjected to stress-relief treatment. This test was used merely for determination of susceptibility to cracking: no tensile, bending or impact tests were made on these specimens.

The results (reported at length and correlated with observations made by SCHAEFFLER (see *Jnl. Amer. Welding Co.*, 1947, vol. 26, Suppl., pp. 601-20)), showed that more than half of the specimens of deposited weld metal contained cracks.

The findings in relation to the influence of the respective variables in composition were as follows:—

(1) Crack susceptibility diminishes with increasing ferrite content. It is suggested that electrodes of the 25-13, 25-20 and 15-35 per cent. chromium-nickel types should, therefore, be used only for buttering ferrite-joint interfaces, or for welding similar types of material.

(2) Crack susceptibility is greater with stabilized electrodes than with unstabilized types: this is attributed to the niobium content of the former.

(3) Electrodes having lime coatings are less liable to cause cracking than neutral or titania-coated electrodes.

(4) It is recommended that when welding ferritic material, root passes should be made with heavy-gauge electrodes, and with relatively low current. This will ensure that the bead has a large cross-section from the start, and that it will not be subjected to excessive dilution in the root passes.

Some lessening of cracking susceptibility may also be secured by careful control of design of welded joints, and in some cases the use of ferritic electrodes may be advisable.

Powder Cutting: Review of Processes

See abstract on p. 188.

Determination of Tantalum and Niobium in Stainless Steels

J. F. YOUNG: 'Analyzing Stabilized Stainless Now Takes Less Time.' *Iron Age*, 1951, vol. 168, July 12, pp. 91-2.

The increasing use of tantalum resulting from the shortage of niobium has necessitated investigation of methods for estimation of tantalum in stainless steel. Wet methods involve expenditure of considerable time, and errors occur due to interfering elements, e.g., tungsten, molybdenum, and titanium. Spectrographic methods are difficult to operate, due to the weakness of the tantalum lines, and a combined spectrographic and wet chemical method has also proved unsatisfactory.

The present note describes a procedure which has been developed in the laboratories of Douglas Aircraft Company, in which the tantalum and niobium are separated as the pentoxides and the tantalum/niobium ratio is determined spectrographically. The niobium is determined, concurrently with the other elements present in the stainless steel, by spectrochemical methods. In this procedure the oxides are separated only once, and the silica is not volatilized, thus reducing the wet chemistry to about half the time involved in conventional methods of estimating niobium+tantalum. Full details are given.

Reference is also made to a point-to-plane method of determining tantalum, which is preferred where it is applicable, due to speed of operation, but its use necessitates a number of standards, which are not at present available.

Tracer Technique in Determination of Lead in Stainless Steels

L. R. STANDIFER and M. G. FONTANA: 'Radio-Autographic Determination of Lead in Stainless.' *Metal Progress*, 1951, vol. 60, July, pp. 65-9.

In connexion with the use of lead as a free-machining addition in stainless steels, investigation was made of the distribution of lead-segregation in cast Durimet 20 (nominal composition nickel 29, chromium 20, molybdenum 1·75 min., copper 3·5, silicon 1·0, carbon 0·07 max., per cent., remainder iron). The amount of lead added was 0·04 per cent., i.e., a quantity well above the solid-solubility limit, which, it was considered, should give a representative picture of distribution at low concentration.

The authors discuss the reasons for choice of the method used, and factors which determined selection of Pb^{210} (radium D) as the isotope most suitable for the purpose. Other possible lead isotopes were eliminated from consideration on account of unsuitable radiation characteristics, too short half-life, or scarcity and cost.

Experimental procedure used in preparation of the radioactive lead from lead-nitrate solution, method of melting the Durimet 20 and introduction of the lead, experimental apparatus used in analysis, and preparation of the radio-autographs, are described in detail, with illustrations.

It was presumed that since Durimet 20 would be a single-phase alloy, lead in excess of the solid-solubility limit would be segregated at the grain boundaries. The radio-autographs indicate, however, that the lead is trapped between small dendrites present within gross grains in the steel, and little evidence was found of preferential segregation of the lead at grain boundaries, in excess of that found between the dendrite branches.

PATENTS

Direct Electrolytic Refining of Nickel from Nickel-containing Matte

A process for refining of nickel directly from nickel-concentration matte comprises (1) electrolysis (in an electrolytic cell provided with a porous partition wall between cathode and anode and with anodes of nickel-concentration matte) of a neutral or weakly acid nickel solution which flows continuously from the cathode chamber into the anode chamber through the porous partition, (2) electrolysis of the copper-containing electrolyte thus obtained, with soluble anodes of nickel-concentration matte, without the use of diaphragms, so that copper is deposited with nickel at the cathode, and (3) returning the de-coppered electrolyte to the cathode chamber in the first cell, where pure metallic nickel is deposited on the cathode.

OUTOKUMPU OY, P. B. BRYK and S. A. AARNISALO. *Swedish Pat.* 124,283.

Extraction of Nickel

A series of eight specifications covers in detail processes for the treatment of ores and mattes containing sulphides of iron, cobalt, copper and nickel with mineral acid (preferably sulphuric acid) under controlled conditions, to recover (*a*) hydrogen sulphide, (*b*) an aqueous solution containing the iron, and (*c*) a solid product containing the remaining elements, which can be further worked up to obtain nickel, cobalt, copper and precious metals. A general description of the processes is given in *Brit. Pat.* 566,375.

M. J. UDY. *Brit. Pats.* 656,140-147.

Extraction of Nickel: Leaching Process

Nickel is recovered from oxygen-containing ores such as limonite, garnierite, lateritic serpentine and roasted sulphides, in high yield, and in relatively concentrated solution (about 1 per cent.), by selective reduction of the nickel compounds to nickel metal, and subsequent leaching with ammonia-ammonium bicarbonate liquor. The process is a two-phase one, and after the second phase the solution is cooled, to deposit magnesium-containing impurities.

NICARO NICKEL CO. *French Pat.* 946,487.

Extraction of Nickel: Separation from Cobalt

Nickel is separated from cobalt contained in nickeliferous cobalt alloys, etc., by treating the nickel-cobalt-containing material (preferably in powdered form) with dilute sulphuric or hydrochloric acid, in

presence of sulphur, selenium, arsenic, tellurium, or antimony. The nickel is thus fixed as an insoluble compound, while the cobalt passes into solution. The separation may be carried out in presence of iron.

STÉ. GÉN. MÉTALLURGIQUE DE HOBOKEN (communication to W. W. TRIGGS). *Brit. Pat.* 655,149.

Chromatographic Separation of Nickel from Cobalt

Mixtures of metal salts may be separated into their component constituents by absorption chromatography, using, preferably, cellulose (filter paper) activated with nitric acid, and various organic solvents. Many applications of the process are cited, including separation of nickel from copper, lead, mercury, arsenic, molybdenum, gold, platinum, palladium, iron, vanadium, zinc, cobalt and magnesium: also cobalt from nickel and iron, and gold, rhodium and iridium from some other precious metals.

MINISTER OF SUPPLY and T. V. ARDEN, F. H. BURSTALL, G. R. DAVIES, R. P. LINSTEAD, and R. A. WELLS, *Brit. Pat.* 654,695.

Separation of Nickel by Precipitation from Solutions containing Cobalt and Nickel

Nickel is precipitated from solution by means of compounds of iron with at least one element of the group sulphur, arsenic, antimony, selenium, tellurium. The compounds are added as such or are formed in the solution. The presence, in the original solution, of metals such as iron, zinc, manganese, copper or lead, does not hinder separation by this method.

STÉ. GÉN. MÉTALLURGIQUE DE HOBOKEN. *Brit. Pat.* 650,595.

See also—

Electrolytic Separation of Nickel from Solutions containing Cobalt and Nickel

A sulphate solution, at pH about 3, and operated at a temperature above 50°C., is electrolyzed with a flowing mercury cathode. The amalgam obtained is made the anode in a stirred dilute-sulphuric-acid bath, at a temperature above 75°C. Nickel goes into solution, with about 2 per cent. cobalt, which is removed by electrolysis at higher current density.

STÉ. GÉN. MÉTALLURGIQUE DE HOBOKEN. *Belgian Pat.* 496,159.

Production of Iron Oxide from Nickel-containing Ores

Finely divided ore consisting mainly of nickeliferous pyrrhotite, pentlandite, chalcopyrite, precious-metal minerals and siliceous gangue, is subjected to a series of flotation and de-sliming operations, with or without magnetic separation, to produce a clean nickeliferous pyrrhotite concentrate and one or more high-grade concentrates containing the copper, the precious metals and the balance of the nickel. These are worked up by known methods.

The nickeliferous pyrrhotite concentrate is roasted under controlled conditions, preferably in an injection-suspension or fluid-bed type of furnace, to obtain a low-sulphur calcine. This is selectively reduced, under controlled conditions of temperature, atmosphere and time, to give nickel in a form substantially all soluble in ammoniacal leaching solutions, while the iron remains in insoluble form. Use of concentrated oxygen for aerating the leaching solution greatly increases the rate of extraction. Yield of nickel is at least 85 per cent., and the iron oxide produced is free from copper and sulphur, and contains less than 0·15 per cent. nickel and less than 3 per cent. silicon.

P. E. QUENEAU, W. K. SPROULE and A. ILLIS, assignors to INTERNATIONAL NICKEL CO., INC. *U.S. Pat.* 2,556,215.

Replenishment of Nickel-Plating Baths

In the electrodeposition of nickel at pH 0·75-3·5 (preferably 1·5), at 100°-160°C., from a chloride-free bath containing (g./L.) nickel sulphate 100-400 (preferably 300), boric acid 10-50 (preferably 30), with insoluble anodes, the bath is continuously replenished by circulating through a replenishing cell. In this cell a direct current of 1-25 amp./sq. ft. is passed between nickel electrodes, and is reversed at intervals of 1-50 seconds, to obtain a net gain of nickel dissolved.

E. J. ROEHL and W. A. WESLEY, assignors to INTERNATIONAL NICKEL CO., INC. *U.S. Pat.* 2,541,721.

Nickel Plating of Powder-Metal Articles

An adherent and corrosion-resisting coating is obtained on a sintered iron-powder base by plating the green compressed compact, and subsequently sintering. During sintering, volatile salts are removed, and the coating fuses to the base. For deposition of nickel on an iron-powder base a bath of the following composition is used:—nickel sulphate 120 g./L., ammonium chloride 15 g./L., boric acid 15 g./L. Sintering treatment is one hour at 1090°C. Alloy plating can be produced in a similar manner, by successive plating with the component metals, e.g., nickel followed by copper, which, on sintering, gives a nickel-copper alloy coating.

EKSTRAND AND THOLAND, INC. *French Pat.* 960,916.

Chemical Deposition of Nickel Coatings

Solutions for use in immersion-deposition of metal films contain pentanedione-2,4; water; and, optionally, a mutual solvent for the two. The films so produced are stated to show hardness and brightness which compare favourably with the corresponding properties of films produced by electrodeposition. Typical examples are given relating to deposition of various base and precious metals, on ferrous or non-ferrous bases which are anodic to them. The deposition of nickel on steel is exemplified by reference to a solution containing pentanedione-2, 4, 50 vol. per cent.; water 25 vol. per cent.; diacetone alcohol 25 vol. per cent., saturated with nickel hydroxide.

L. PESSEL, assignor to RADIO CORPN. OF AMERICA. *U.S. Pat.* 2,560,979.

Degasification of Electrodeposited Coatings

Hydrogen absorbed in electrodeposits of nickel or chromium is removed by immersing the coated material in a bath of water, together with one or more

of the anodes used, and short-circuiting them. The process may be hastened by passing a small current.
ÉTAT FRANCAIS, represented by SEC. D'ÉTAT A LA PRODUCTION INDUSTRIELLE. *French Pat.* 972,910.

Nickel Additions to Lead Baths for Hot-Dipping

Continuous, smooth coatings of lead are obtained, on surfaces of iron, steel, copper or copper alloys, by hot-dipping in a lead bath which contains 0·01-0·5 per cent. of nickel. The proportion of nickel normally used according to this invention compares favourably with the higher proportions of tin or other intermetallic-compound-forming additions formerly proposed, and the resulting economies are considerable. The stability of lead coatings so produced makes it possible to build up on them lead coatings of any desired thickness, by burning-on more lead. Typical examples of the treatment are given.
BRIT. NON-FERROUS METALS RESEARCH ASSOCN. (inventors G. L. J. BAILEY and H. C. WATKINS)
Brit. Pat. 657,025

Stripping of Nickel Coatings from Steel

Aqueous solutions for stripping of nickel, copper, zinc, silver or cadmium, from iron, steel or chromium surfaces, contain an alkali metal chlorite and an alkali metal cyanide, within the range 5 gr. chlorite and 1 gr. cyanide per litre, up to saturation of the respective reagents in the solution. Suitable ratios of the constituents, and the rate of stripping of nickel obtained as a function of temperature for a given solution, are shown graphically.
W. R. MEYER, assignor to ENTHONE, INC.
U.S. Pat. 2,561,065.

Stripping of nickel, chromium, silver, tin, lead, copper, zinc and cadmium deposits from ferrous bases is accomplished, without risk of attack of the basis metal, by the use of aqueous solutions containing sodium carbonate (100-300 g./L.) and chromic acid (50-200 g./L.). The very close control of pH generally required in stripping operations is not necessary when using such solutions, and the ferrous base is not attacked.
F. PASSAL, assignor to UNITED CHROMIUM, INC.
U.S. Pat. 2,561,222.

Protective Coatings for Gas-Turbine Blades

Heat- and creep-resistance of alloy gas-turbine blades, combustion chambers and other high-temperature components is improved by coating externally with one or more layers of adherent enamel, which may be finally metal coated. In an example cited, a nickel-chromium steel blade is coated electrolytically with nickel, sprayed (to increase adherence) with a pre-coat of enamel containing nickel and bismuth ions but no refractory oxides, and then with a main coat of zirconium oxide-base enamel containing oxides of molybdenum, vanadium and tungsten. This final coating is baked on, primed with chromium (by thermal decomposition of an aqueous chromium salt solution which has been brushed on the surface), and finally chromium plated.
STÉ. NAT. D'ÉTUDE ET DE CONSTRUCTION DE MOTEURS D'AVIATION and Y. LE SECH. *Brit. Pat.* 656,503.

Nickel-Coating of Ceramics

A metal coating is formed on ceramic articles by applying a thin layer of powdered iron, molybdenum, tungsten or nickel containing a small proportion (preferably 10 per cent.) of powdered manganese, and sintering in hydrogen or in vacuo. A treatment of half an hour at 1350°C. is mentioned. The metallized ceramic may be soldered, with soft or hard solders, to metals or other metallized ceramics.
BRITISH THOMSON HOUSTON CO., LTD. *Brit. Pat.* 656,724.

Nickel Alloys for Glass-to-Metal Seals

Liability to development of tension stresses in glass, on application of a force normal to the plane of the glass-to-metal seal, is reduced by using an iron-nickel-chromium alloy having a coefficient of thermal expansion about 10 per cent. lower than that of the glass, so as to leave a residual radial stress, after annealing, of about 70-300 kg./cm². A suitable alloy for use with soft glass contains nickel 42·0, chromium 4·5, aluminium 0·1, silicon 0·2, sulphur 0·015, phosphorus 0·015, manganese 0·25, carbon 0·02, per cent., iron balance. The core is coated with a thin layer of nickel and finally with chromium.
R. F. DORAN, assignor to SYLVANIA ELECTRIC PRODUCTS, INC. *U.S. Pat.* 2,555,877.

Nickel Alloys for Compensating Balance Springs for Watches and Chronometers

Two types of alloy are specified: containing (1) tantalum 0·1-6, nickel 29-42, chromium 4-10, tungsten 1-5, vanadium 0-2, manganese+silicon 0·5-5, carbon 0·5-1, per cent., iron balance, or (2) niobium+tantalum 0·1-8, nickel 29-42, chromium 4-10, tungsten 1-5, vanadium 0-2, manganese 0·5-5, carbon 0·5-1, per cent., balance.
E. DUBOIS. *French Pat.* 969,118.

Production of Nickel-Iron Alloys of Controlled Magnetic Properties

Nickel-iron alloys containing nickel 45-55 per cent., with specified low maxima of silicon, manganese, carbon, cobalt, copper, and aluminium, balance iron, and characterized by a rectangular hysteresis loop, are made by the following method: The raw materials are melted in an electric-arc furnace, and oxidizable impurities are eliminated. The slag is then removed, a new lime slag is added, the melt is deoxidized, metal additions are made as required, and the metal is cast. The ingot is hot-rolled to 10-100 times the required final gauge, annealed in pure dry hydrogen, cold-rolled to a reduction of 90-99 per cent. without further annealing, slit, cut to final width and annealed to develop the required magnetic properties.
C. A. SCHARSCHU, assignor to ALLEGHENY LUDLUM STEEL CORPN. *U.S. Pat.* 2,558,104.

Complex Precipitation-Hardening Alloys for High-Temperature Service

Parts required to withstand stress at 1500°F. (815°C.) and above are made from a precipitation-hardened austenitic alloy containing nickel 15-35, cobalt 20-40,

chromium 17-22, molybdenum 3-15, tungsten 1-9, manganese 0·5-3, silicon 0·1-0·7, carbon up to 0·2, per cent., balance iron, with less than 0·5 per cent. impurities. The following relation among the elements is specified:—

$$\%Mo+0\cdot8\,(\%Cr)+0\cdot75(\%W+\%Mn)+1\cdot2\,(\%Si)-0\cdot2(\%Ni)-0\cdot125(\%Co)=19\text{-}24$$

Solution treatment is at 2200°-2375°F. (1204°-1300°C.) for 0·5-4 hours, followed by quenching, and subsequent ageing at 1500°-1700°F. (815°-926°C.) for 20-240 hours.

H. SCOTT and R. B. GORDON, assignors to CANAD. WESTINGHOUSE CO., LTD. *Canad. Pat.* 473,774.

Nickel-Cobalt-base Alloys for High-Temperature Service

Alloys claimed as suitable for gas-turbine parts contain carbon 0·10-0·70, chromium 12-35 (preferably 12-22), nickel 10-31, cobalt 9-50, per cent., and substantially equal amounts of molybdenum, tungsten and niobium, each within the range 2-10 per cent. (preferably 2-6 per cent.) Balance, if any, is iron, with the exception of the usual impurities, and the alloys may contain silicon 0·2-1, manganese 0·4-1 per cent. Heat-treatment comprises heating at 2150°-2400°F. (1177°-1305°C.) for one hour, water quenching, ageing at 1300°-1600°F. (704°-870°C.) for about 16 hours, and air cooling. Fatigue-test data are presented.

ALLEGHENY-LUDLUM STEEL CORPN. *Brit. Pat.* 654,354.

Composition and Treatment of Chromium-Nickel-Aluminium Precipitation-Hardenable Steels

A series of four patents relates to various types of austenitic nickel-chromium stainless steel containing aluminium, with or without other modifying additions.

(1) Composition limits are determined graphically within the range nickel 9·5 with chromium 12, per cent. to nickel 5·4-6·5 with chromium 19, per cent. Preferred range nickel 6·5-7·25, chromium 15·5-16·5, per cent. Carbon is 0·02-0·12, aluminium 0·50-2·50, manganese up to 8·0, silicon up to 2·0, molybdenum up to 3·0, per cent., balance iron. The steel is annealed at 1300°-1800°F. (705°-980°C.), quenched, and precipitation-hardened at 750°-1000°F. (400°-538°C.).

(2) Steel of the type described above may have sulphur or selenium additions, to give free-machining properties. A double precipitation-hardening heat-treatment is specified.

(3) Steel of similar type is annealed at 1800°-2000°F. (980°-1093°C.), quenched, transformed by cold treatment at a temperature below about −30°F. (−34°C.), and precipitation-hardened at 750°-1000°F. (400°-538°C.).

(4) Steel of similar type is heat-treated as follows: annealed at 1800°-2000°F. (980°-1093°C.), quenched, stabilized by treatment at 600°-1100°F. (315°-593°C.), transformed either by treatment at a temperature below −30°F. (−34°C.) or at 1200°-1600°F. (648°-870°C.), and finally precipitation-hardened by heating at 750°-1000°F. (400°-538°C.).

G. N. GOLLER, assignor to ARMCO STEEL CORPN. *U.S. Pats.* 2,505,762-4; 2,506,558.

Cobalt- and Niobium-free Steel for High-Temperature Service

Steel showing high creep-resistance at temperatures up to at least 700°C. is characterized by the absence of cobalt and niobium. Essential constituents (preferred composition in brackets): carbon up to 0·4 (0·15-0·3), silicon up to 1 (0·2-0·4), manganese up to 3 (0·2-1), chromium 9-17 (13·5-15), nickel 7-12 (8-11), molybdenum 2-3 (1·75-2·25), copper 1-4 (2-2·75), titanium 0·25-1 (0·5-1), per cent., balance iron and impurities, with or without tungsten up to 2 per cent.

H. W. KIRKBY and C. SYKES, assignors to THOS. FIRTH AND JOHN BROWN, LTD. *U.S. Pat.* 2,556,373.

Niobium Additions to High-Temperature Alloys

The composition of alloys covered by British Patent 616,207 (see *Nickel Bulletin*, 1949, vol. 22, No. 4, p. 67) is modified by substitution of niobium (0·25-2·5 per cent.) for the whole or part of the titanium. Titanium+niobium is not more than 2·5 per cent. The modified alloy contains carbon up to 1·5, silicon up to 2·0, manganese up to 2·0, chromium 12-20, nickel 25-15, cobalt 7-40, molybdenum 2-6, copper 2-6, niobium 2·5-0·25, titanium up to 1·95, per cent., iron balance and not less than 10 per cent. The material is claimed to be suitable for stressed components operating at temperatures up to 850°C. The lower limit of cobalt may, in some cases, be reduced to 6·61 per cent.

FIRTH VICKERS STAINLESS STEELS, LTD. and C. SYKES. *Brit. Pat.* 655,416.

Thermal Treatment of Creep-Resisting Steels

The creep-resistance of high-alloy chromium-nickel steels covered by *Brit. Pat.* 647,701 (see *Nickel Bulletin*, 1951, vol. 24, No. 4, p. 93) is increased by solution heat-treatment, preferably in a neutral or reducing atmosphere rich in hydrogen and nitrogen, at 20°-150°C. below the incipient melting point (1300°-1380°C.), and then cooled. The treatment is suitable for i.c. engine valves and gas-turbine parts.

WM. JESSOP AND SONS, LTD., D. A. OLIVER and G. T. HARRIS. *Brit. Pat.* 657,021 (patent of addition to 647,701).

Precipitation-Hardenable Steel Springs

Stainless-steel springs showing good elastic properties (proportional limits 65,000-195,000 p.s.i.: 58-87 tons per sq. in., or above) are made from steel containing chromium 16·5-18·5, nickel 2·85-5·60, copper 3·0-5·0, carbon up to 0·16, nitrogen up to 0·13, per cent., balance iron. Carbon+nitrogen content is specified as not exceeding 0·21 per cent. The steel is annealed, cold-worked and precipitation-heat-treated, at specified temperatures, to increase the elastic properties.

G. N. GOLLER, assignor to ARMCO STEEL CORPN. *U.S. Pat.* 2,553,707.

In a related patent the composition limits are chromium 16·65-17·5, nickel 6·75-7·6, carbon 0·06-0·08, aluminium 0·60-1·0, manganese up to 8·0, silicon

up to 2·0, molybdenum up to 3·0, per cent., balance iron. Proportional limit range: 40,000-230,000 p.s.i.: 18-102·5 tons per sq. in., or above.

G. N. GOLLER, assignor to ARMCO STEEL CORPN. *U.S. Pat.* 2,553,707.

Corrosion-Resisting Valve Alloy

Poppet valves resistant to corrosion by lead oxide are made from steel containing *either* chromium 10-35, niobium 0·1-5·0, titanium 1·5-3·0, aluminium 0·2-1·5, iron 0·1-20·0, silicon 0·05-8·0, carbon up to 0·25, manganese 0·05-3·0, per cent., balance nickel and/or cobalt, *or* nickel 14, tungsten 2·5, carbon 0·35, per cent., balance iron.

THOMPSON PRODUCTS, INC., K. M. BARTLETT and M. S. ROUSH. *U.S. Pat.* 2,548,092.

Hot-Forging of Nickel-Chromium-Molybdenum Steel Rotors

A turbine rotor of steel containing chromium 16, nickel 25, molybdenum 6, per cent. is formed by hot-forging a billet successively at 1950°F. (1063°C.). in several dies, to form a blank, heating the blank to 2200°F. (1204°C.), holding at that temperature for 2½ hours, quenching, re-heating to the same temperature, and hardening by successive forgings at 1200°F. (650°C.) in several dies.

W. N. MARTIN and J. Y. RIEDEL, assignors to BETHLEHEM STEEL CO. *U.S. Pat.* 2,560,973.

Cerium and Lanthanum Additions to Improve Workability of High-Temperature Alloys

Cerium, lanthanum or other rare earths contained in mischmetall are used to improve the hot-working properties of ferrous and non-ferrous alloys containing nickel, at least one of the elements chromium, molybdenum and tungsten, 0-0·5 per cent. carbon, and varying proportions of additional elements. The amount of the rare-earth addition needed depends on the nickel content, varying from 0·02-1·10 per cent. cerium and/or lanthanum with 4 per cent. nickel to 0·02-0·15 per cent. with 70 per cent. nickel. The additional elements which may be present in the alloys covered are iron, copper, nitrogen, cobalt, manganese, silicon, niobium, tantalum, vanadium and titanium, in wide range. Many typical compositions are given.

(The patent covers alloys referred to in the abstract appearing in *Nickel Bulletin*, 1951, vol. 24, No. 8, p. 181).

C. B. POST and D. G. SCHOFFSTALL, assignors to CARPENTER STEEL CO. *U.S. Pat.* 2,553,330.

Low-Temperature Annealing of Austenitic Steels

The elastic properties of cold-worked nickel-chromium stainless steels are improved by heating at 75°-700°C. for a time sufficiently short to prevent deterioration of the surface or hardening of the steel. For an 18-8 chromium-nickel steel a treatment of 8-200 hours at about 200°C. is recommended.

R. FRANKS, assignor to ELECTRO METALLURGICAL CO. OF CANADA, LTD. *Canad. Pat.* 476,069.

Austenitic Nickel-Chromium Steels of Improved Machinability

Machinability of nickel-chromium steels containing niobium, with or without tantalum and/or vanadium, is improved by addition of selenium and/or tellurium and/or sulphur. The range of composition claimed is as follows: carbon 0·08-1·0, silicon 0·1-2·0, manganese 0·1-5·0, nickel 5-30, chromium 21-5, tungsten and/or molybdenum 1·5-15·0, with niobium and/or tantalum and/or vanadium 0·25-15, cobalt 3-30, nitrogen 0-0·3, copper 0-6, selenium 0·1-2·0, iron balance. Iron is to be not less than 33, and nickel+chromium not less than 24, per cent. Niobium is in specified minimum relationship to the tantalum and/or vanadium when present. Heat-treatment of the alloys is laid down.

W. JESSOP AND SONS, LTD., D. A. OLIVER and G. T. HARRIS. *Brit. Pat.* 654,294.

Nickel-Chromium Austenitic Steel Welding Rods

Hot-cracking of welds made in austenitic nickel-chromium steels containing niobium is prevented by use of a coated electrode made from steels of the same type containing niobium 0·9-8, manganese 0·6-3, per cent.

GEBR. BÖHLER AND CO., A.G. *French Pat.* 968,580.

Butt-Welded Austenitic Nickel-Chromium Steel Gas-Turbine Components

The patent describes gas-turbine rotors, or other parts for high-temperature service, made from two portions butt-welded together. The portion more nearly adjacent to the high-temperature source is of austenitic steel of the type described in British Patent 647,701 (preferred composition carbon 0·2-0·6, silicon 0·2-1·5, manganese 0·1-1·2, nickel 5-25, chromium 21-10, tungsten+molybdenum 1·5-10, niobium and/or tantalum and/or vanadium 1·0-8·0, cobalt 3-30, copper 0-6, nitrogen 0-0·06, iron not less than 33, per cent.). The other part of the components is made from a steel containing carbon 0·03-0·25, silicon 0·20-2·0, chromium 15-25, nickel 7-16, niobium (and/or equivalent metals) 5-30 times the weight per cent. of carbon.

WM. JESSOP AND SONS, LTD., D. A. OLIVER and G. T. HARRIS. *Brit. Pat.* 654,922.

Austenitic Nickel-Chromium Steel Sound-Recording Wire

A magnetic material for sound-recording wires and ribbons consists of an austenitic steel containing chromium 17-20, nickel 7-10, carbon 0·03-0·25, per cent., with or without small amounts of niobium, titanium, vanadium, and nitrogen, balance iron. The wire is first cold-drawn to a stage near the final diameter, then heat-treated at 500°-700°C. to produce precipitation of carbides, and finally lightly cold-drawn to size. If desired, the first drawing may be done in two stages, with intermediate stress-relief annealing treatment, followed by a second drawing, the precipitation heat-treatment and the final drawing.

CIE. FRANCAISE THOMSON-HOUSTON. *French Pat.* 954,107.

Attention is drawn to the fact that many of the names of materials mentioned in The Nickel Bulletin are *Registered Trade Marks.*

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